Museum of Comparative Zoology

Harvard University

Annual Report

2020•2021

About the MCZ

The Museum of Comparative Zoology at Harvard University is a global center for research and education focused on the biology and evolution of animal life. The MCZ collections comprise approximately 21 million extant and fossil invertebrate and vertebrate specimens, which are a focus of research and teaching for the MCZ, Harvard, and students and researchers around the globe.

Contents

Director's Message

We look forward to a return to campus . . . but with a mask and no hugging!

In my first message as director, I am ecstatic to address you and welcome our students, staff and researchers back to campus. Admittedly, it will not be the same as it was prior to 2020, but seeing colleagues, students and friends around campus feels pretty good to me.

We are continuing many cautionary measures, as in the back of our minds we know we may need to take one or more steps back at any given point, depending on the evolutionary success of a virus, which is an organism that we often ignore in our phylogenetic thinking (and the missteps of a species we think of as being on top of the animal tree of life!) And just like that, I have exposed my phylogenetic side.

It is a great honor and a privilege to write this message and to thank our former director, Prof. James Hanken, for the 20 years he devoted to our esteemed Museum, ending with an unprecedented pandemic that, as he said in his message from one year ago, "has been the MCZ's preoccupation for most of 2020."

It is now time to look forward as we return to the classrooms, labs and museum spaces, but without losing sight of the pandemic and the great cost to ourselves, our loved ones, and countless others who are too often reduced to statistics. And let us not forget that while we are resuming many of our daily operations, many museums around the world are less fortunate.

But we have also learned and grown over these past months. Given inequalities that have become increasingly evident, we know we must make the MCZ more inclusive and welcoming to people of all backgrounds. With your help, I will continue the task of recognizing the work of past contributors to the Museum who did not get their deserved credit while removing references to Louis Agassiz, our Museum's founder, who fostered ideas of racial disparity and inequality. In early 2020, we began the process of renaming two MCZ conference rooms in honor of Robert A. Gilbert and Ruth D. Turner, two unsung heroes in the MCZ.

We will continue growing in areas of global impact, especially the contribution of our collections to broader initiatives of biodiversity informatics. I see a future for natural history museums and the genome–phenome connection, where I hope we can become a world leader. We are on our way, as we have cryo-preserved parts of our most crucial specimens.

Finally I want to recognize our esteemed colleague Prof. Richard "Dick" Lewontin, who passed away on July 4, 2021, a date he probably chose to remind us that heroes are also rebels. He will be sorely missed by his colleagues and friends. His accomplishments are reviewed elsewhere in this report.

Once this report reaches you, I expect the MCZ corridors, collections and classrooms to be the busy places we knew them to be before the COVID-19 pandemic. In the meantime, please enjoy reading about our activities in the following pages and join me in congratulating the students, staff, researchers and faculty for a productive year.

Juan Giribet

Gonzalo Giribet
Director

About the cover: A fossilized soft-bodied arthropod, *Thelxiope holmani* (MCZ IP-197957), from the mid-Cambrian Wheeler Formation in Utah. Photo by Javier Ortega-Hernández and Rudy Lerosey-Aubril.

Opposite page: An undescribed species of *Epiperipatus* (MCZ IZ-131442) collected and photographed by Gonzalo Giribet during a National Geographic–funded expedition to the Rio Negro in Roraima, Brazil.

An Era Ends, and a New One Begins

As Gonzalo Giribet assumes the directorship from James Hanken, the MCZ reflects on the significant accomplishments of the last 20 years and the bright promise of the Museum's future.

Melissa Aja

James Hanken

Jesus Troncoso

Gonzalo Giribet

James Hanken joined the MCZ in 1999 as a faculty member and curator in Herpetology, and, within a year, became director of the MCZ. He was only the ninth director since the founding of the Museum in 1859, and during his 20-year tenure he guided the MCZ through a period of profound progress. In the beginning, it was widely recognized that the Museum needed an injection of activity—new blood, both in the faculty ranks and the student population. It was also clear that the facilities, some as old as the Museum itself, were outdated and the collections were bursting at the seams. These broad priorities shaped his focus over the next two decades.

Collections-based research had been changing dramatically, with laboratory-based work—genetics and molecular biology—becoming much more common, highlighting the need for new, sophisticated labs with digital imaging capabilities and high-powered computers. Hanken has been able to meet these needs with a substantial renovation of the collection spaces and a new 50,000-square-foot, state-of-the-art collections facility in the Northwest Building. Renovations have also occurred in offices and research laboratories, with the addition of a shared digital imaging facility and a cryogenic frozen-tissue collection facility.

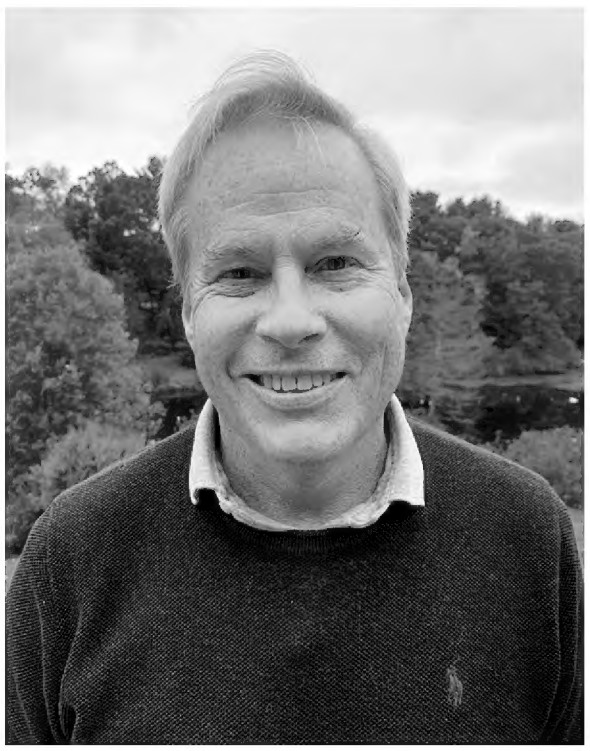
According to Hanken, the best way to accomplish the MCZ's mission to push the boundaries of knowledge and make new discoveries is to hire talented faculty-curators. Over the years he has facilitated these searches and brought them to successful conclusions, working to diversify the ranks in the process.

As he becomes "a plain old faculty member and curator" in July 2021, Hanken says, "The MCZ is in a good place right now, but we can't afford to rest on our laurels. Biodiversity science and the natural history community are changing constantly, so we have to continue to work hard or we'll be left behind."

Assuming the directorship—and the opportunities and challenges of MCZ's future—is **Gonzalo Giribet**, faculty member and curator in Invertebrate Zoology, who joined the MCZ in 2000. Fascinated by shells and creatures of the sea since he was a young boy in Spain, Giribet's career has centered on understanding how animal diversity originates and persists through time, so his areas of inquiry naturally include biodiversity, ecology, systematics and biogeography. He is also a self-professed "museum guy."

Because museums are a library of biodiversity, the specimens that they contain are an incredibly valuable resource. "One of my priorities," says Giribet, "is to bring the untapped resources of our collections to the forefront by making them more interesting to researchers and the general public. One way to do this is by connecting the specimens to their genomes, especially for those that are very rare or extinct." Giribet feels that it is important to continue developing tools that will allow the preservation of the DNA of these organisms and begin to incorporate genome sequencing and DNA storage as a normal procedure in a modern natural history collection. "Analysis of genomes in older collections specimens, when compared to those same species today, can illuminate changes from environmental, often human-induced, impacts, demonstrating the continued importance of preserving these collections for the long term."

Faculty-Curator Profiles



Andrew A. Biewener
Charles P. Lyman Professor of Biology
Director, Concord Field Station

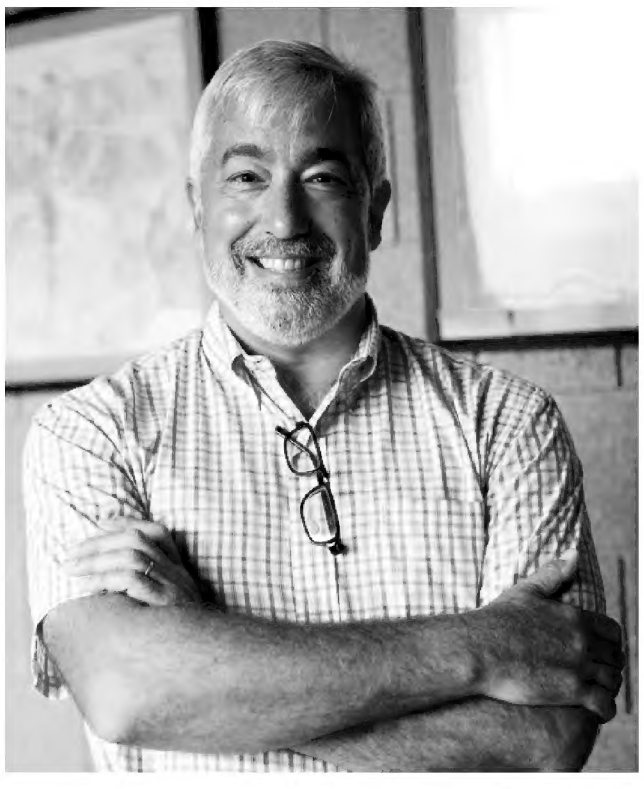
Prof. Biewener studies the biomechanics and neuromuscular control of animal movement on land and in the air. His goal is to understand general principles that govern the biomechanical and physiological design of vertebrate animals related to movement in natural environments, work with engineers to develop bio-inspired robotic designs, and develop improved neuromuscular models for treating human movement disorders.

Scott V. Edwards
Professor of Organismic and Evolutionary Biology
Alexander Agassiz Professor of Zoology
Curator of Ornithology

Prof. Edwards' research focuses on the evolutionary biology of birds and related species, combining field, museum and genomics approaches to understand the basis of avian diversity, evolution and behavior.

Current projects use genomics technologies to study the evolution of flightlessness and other traits in birds; phylogeography and speciation in Neotropical and Australasian birds; and the genomics of host–parasite coevolution between house finches and a recently acquired bacterial pathogen, *Mycoplasma*.

Kris Snibbe/Harvard University

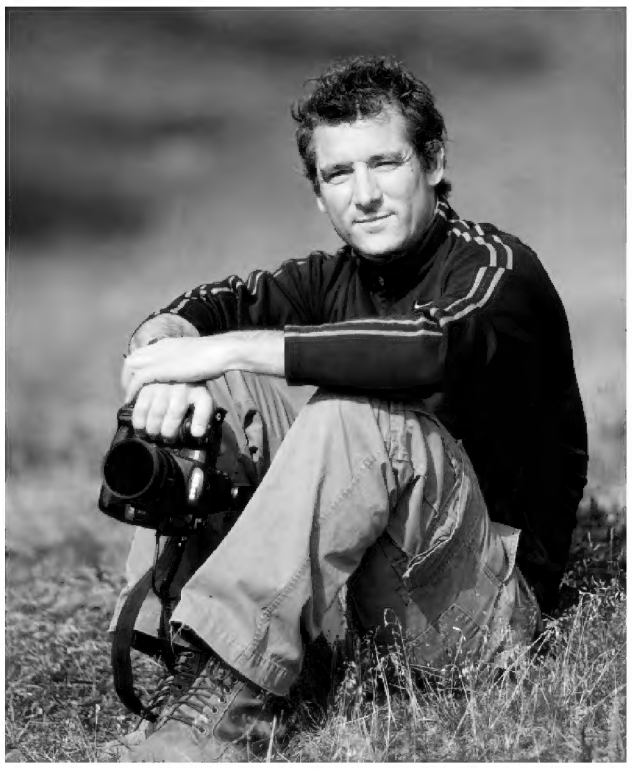


Stephanie Mitchell

Brian D. Farrell
Monique & Philip Lehner Professor for the Study of Latin America
Professor of Organismic & Evolutionary Biology
Curator of Entomology
Faculty Dean, Leverett House

Prof. Farrell's research is broadly concerned with the evolution of ecological interactions between host plants and animals and their parasites, pests and pathogens, such as insects and other tiny consumers. His current projects include applying next-generation sequencing to speciation and phylogenetic studies of associated species of beetles and plants, documenting biodiversity in the Dominican Republic, and repatriating digital information from scientific specimens of insects and fossils in museums to their countries of origin.

FACULTY-CURATOR PROFILES



Casey Dunn

Gonzalo Giribet

Alexander Agassiz Professor of Zoology

Professor of Organismic & Evolutionary Biology

Curator of Invertebrate Zoology

Harvard College Professor

MCZ Director (beginning July 2021)

Prof. Giribet's primary research focuses on the evolution, systematics and biogeography of invertebrate animals, including the use of morphology and next-generation sequencing techniques.

Current projects in the Giribet lab include a comprehensive study of the harvestmen of New Zealand, their systematics and biogeography; mollusk phylogenomic projects; and exploring techniques to use degraded DNA from old museum specimens in phylogenomics and population genomics. The lab also works on other projects on systematics and biogeography of arthropods and onychophorans, among other groups.

Kris Snibbe/Harvard University

Hopi E. Hoekstra

Professor of Organismic & Evolutionary Biology

Professor of Molecular & Cellular Biology

Alexander Agassiz Professor of Zoology

Curator of Mammalogy

Howard Hughes Medical Institute Investigator

Prof. Hoekstra combines field and laboratory work to understand the evolution of mammalian diversity. Her research focuses on the genetic basis of morphological and behavioral variation, primarily in rodents, identifying both the evolutionary processes and the molecular mechanisms responsible for traits that help organisms survive and reproduce in the wild. Research in the Hoekstra lab integrates ecological, behavioral, genetic, developmental and neurobiological approaches.

Catherine Weisel

James Hanken

Professor of Biology

Alexander Agassiz Professor of Zoology

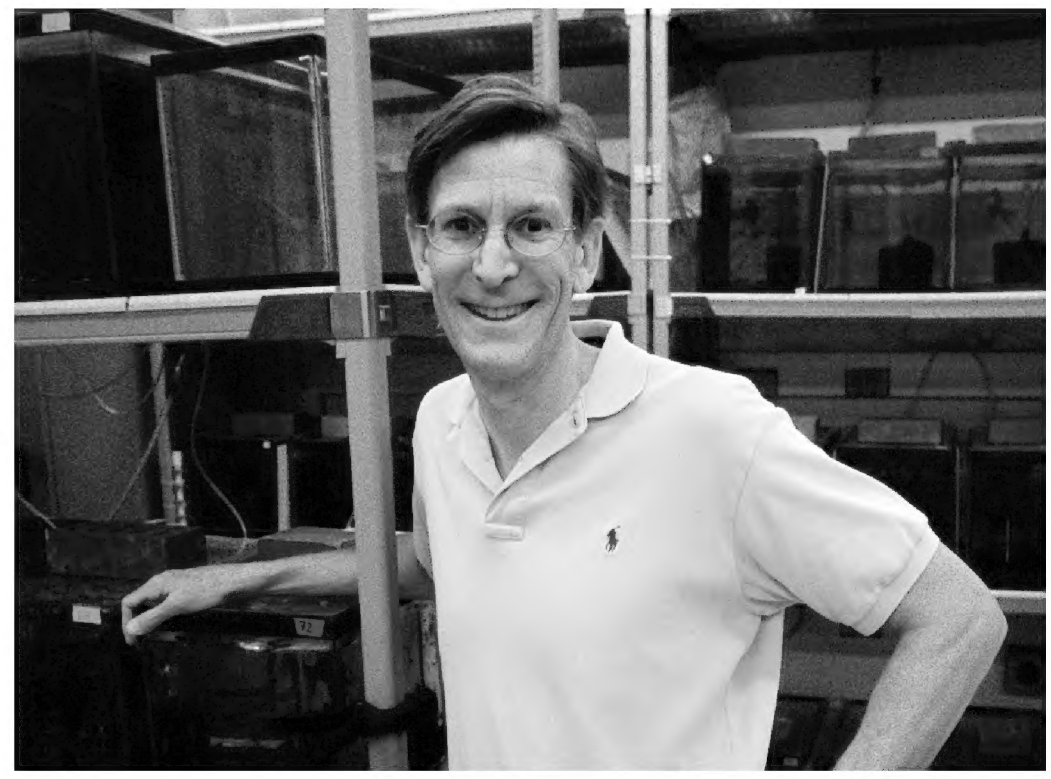
Curator of Herpetology

Acting Curator of Malacology

MCZ Director (through June 2021)

Prof. Hanken utilizes laboratory-based analyses and field surveys to examine morphological evolution, developmental biology and systematics.

Current areas of research include the developmental basis of morphological novelty and life-history evolution; the systematics and evolution of neotropical frogs and salamanders; and museum-based digital imaging technology.



Stephanie Mitchell

George V. Lauder

Henry Bryant Bigelow Professor of Ichthyology

Curator of Ichthyology

Harvard College Professor

Prof. Lauder's research focuses on the biomechanics of fishes and the development of robotic models for studying aquatic locomotion.

His current studies focus on the structure and function of shark skin and other fish surface structures and research with various robotic fish models, including a tuna robot. Additional broad interests include biological fluid mechanics and theoretical approaches to the analysis of form and function in organisms.

Javier Ortega-Hernández

Assistant Professor of Organismic & Evolutionary Biology

Curator of Invertebrate Paleontology

Prof. Ortega-Hernández's research focuses on the evolution of metazoans that first appeared and rapidly diversified during the Paleozoic Era (ca. 541 to 251 million years ago). His group specializes in the study of exceptionally preserved Cambrian and Ordovician fossil biotas around the world, with a strong interest in the morphology, phylogeny and development of panarthropods and their relatives. The lab combines traditional paleontology with cutting-edge techniques to investigate exceptional fossils, test macroevolutionary hypotheses through deep time, and better understand the origin of the major animal groups that have shaped the biosphere for more than 500 million years.

Paul Whatmough

Stephanie E. Pierce

Thomas D. Cabot Associate Professor of Organismic & Evolutionary Biology

Curator of Vertebrate Paleontology

Prof. Pierce's research is focused on major morphological and ecological transitions in vertebrate evolution through an examination of the fossil record. Her work tends toward 3D modeling and experimentation of the musculoskeletal system, with particular attention to the link between form and function. Current projects focus on two key events in the fossil record, the fish-to-tetrapod and "reptile"-to-mammal transitions.

Isabella Kirkland

Naomi E. Pierce

Sidney A. & John H. Hessel Professor of Biology

Curator of Lepidoptera

Prof. Pierce's research focuses on the behavioral ecology of species interactions, particularly the coevolution between plants, pathogens and herbivores, and symbioses between ants and other organisms. Her laboratory integrates approaches from phylogenetics, ecology, behavior, genomics and comparative methods to investigate patterns of reciprocal adaptation and diversification exhibited by organisms that live in close association with each other.

Mansi Srivastava

John L. Loeb Associate Professor of the Natural Sciences

Curator of Invertebrate Zoology

Tim Bradbury

Prof. Srivastava's research focuses on understanding the evolution of animal development and regeneration. Her group utilizes the three-banded panther worm, *Hofstenia miamia*, which she has developed as a new acoel model system. Acoels represent an understudied phylum that is distantly related to other well-studied regenerative species, which allows her group to study genetic mechanisms from a comparative perspective. Current projects in the lab range from identifying gene regulatory networks for regeneration to determining the embryonic origins of pluripotent stem cells to understanding the evolution of centralized nervous systems.

Emeritus Profiles

Justin Ide

A. W. "Fuzz" Crompton

Fisher Professor of Natural History, Emeritus

Prof. Crompton, former curator in Mammalogy, was the director of the MCZ from 1970 to 1982, having served as director of both the Peabody Museum of Natural History at Yale University and the South African Museum in Cape Town. His primary research interests include the origin and evolution of mammals, functional anatomy, and neural control and evolution of feeding in recent and fossil vertebrates. Prof. Crompton received two Guggenheim fellowships for his research on vertebrate paleontology and functional morphology, and in 2011 received the Romer-Simpson Medal from the Society of Vertebrate Paleontology.

Edward O. Wilson

Honorary Curator of Entomology
Pellegrino University Professor, Emeritus

Beth Maynor Finch

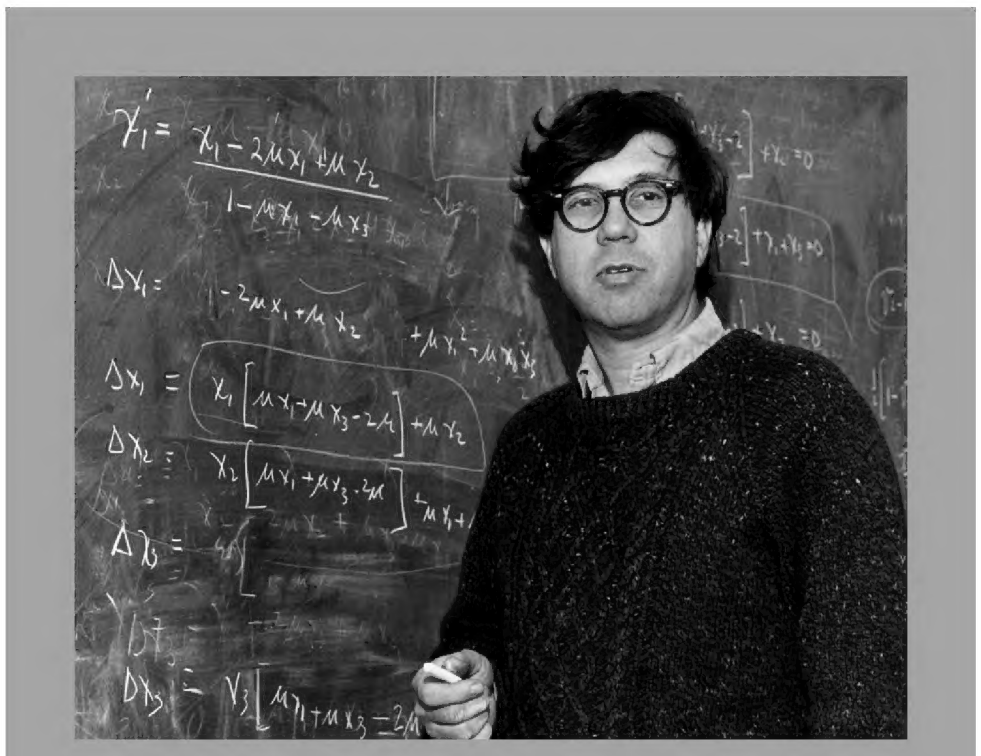
Prof. Wilson is considered the founder of sociobiology and has developed the basis of modern biodiversity conservation. He has received many of the world's leading prizes in recognition of his research, creative literature and environmental activism. Prof. Wilson was awarded two Pulitzer Prizes for his books *The Ants* (1990, with Bert Hölldobler) and *On Human Nature* (1978). He received the TED Prize in 2007, where he articulated the concept of the Encyclopedia of Life, and the Hubbard Medal in 2013, the rarely given highest award of the National Geographic Society.

Robert M. Woollacott

Professor of Biology, Emeritus

Prof. Woollacott joined the faculty in 1972 and retired in 2018.

His teaching and research focus on the reproduction of marine invertebrates and human impacts on life in the sea.



In Memoriam: Richard C. Lewontin

On July 4, 2021, population geneticist Richard "Dick" Lewontin, Emeritus Professor of Biology and Alexander Agassiz Professor of Zoology, passed away at the age of 92. He left an indelible imprint on the field of evolutionary biology through his research, writing and mentorship.

After finishing his undergraduate degree at Harvard, Dick trained under the supervision of the famous *Drosophila* geneticist Theodosius Dobzhansky at Columbia. Later, at the University of Chicago, he worked with biochemist Jack Hubby, and their work effectively set the agenda for both empirical and theoretical population genetics for the ensuing decades and to the current era of population genomics.

In 1973, Dick joined the MCZ to serve as a curator in population genetics, where he created an environment that attracted many talented trainees and visitors.

A year later, the publication of his book *The Genetic Basis of Evolutionary Change* solidified his position as a leader in the field. In addition to his work in *Drosophila*, he also made profound contributions to the field of human genetics throughout his career. In 2015 Dick was awarded the Crafoord prize and in 2017 the Genetics Society of America's highest honor, the Thomas Hunt Morgan Medal.

He was deeply loved and revered by those close to him. He will be deeply missed and not soon forgotten.

Edited from the **In Memoriam by Hopi Hoekstra and Dmitri Petrov** *that appeared on the website of the Society of Molecular Biology & Evolution,* **smbe.org**

Courses Led by Faculty-Curators

Academic Year 2020–2021

George Lauder

OEB 130: Biology of Fishes

Organismic and Evolutionary Biology

OEB 10: Foundations of Biological Diversity

Brian D. Farrell, Mansi Srivastava (and Elena Kramer, Ann Pearson)

An integrated approach to the diversity of life, emphasizing how chemical, physical, genetic, ecological and geologic processes contribute to the origin and maintenance of biological diversity.

OEB 57: Animal Behavior

Naomi E. Pierce (and Bence P. Ölveczky)

A review of the behavior of animals under natural conditions, with emphasis on both mechanistic and evolutionary approaches.

OEB 112: Arthropod Biology: Arachnids and Myriapods, Their Biology and Evolution

Gonzalo Giribet

Developed for remote teaching, introduces the evolutionary history and biology of arachnids, myriapods and related groups, learning their taxonomy and anatomy as well as their role as model organisms to understand phenomena such as segmentation or appendage specification.

OEB 130: Biology of Fishes

George V. Lauder

Explores the unparalleled diversity of fish across different aquatic environments including deep seas, intertidal zones, coral reefs, polar waters, the vast Amazonian basin and great East African lakes.

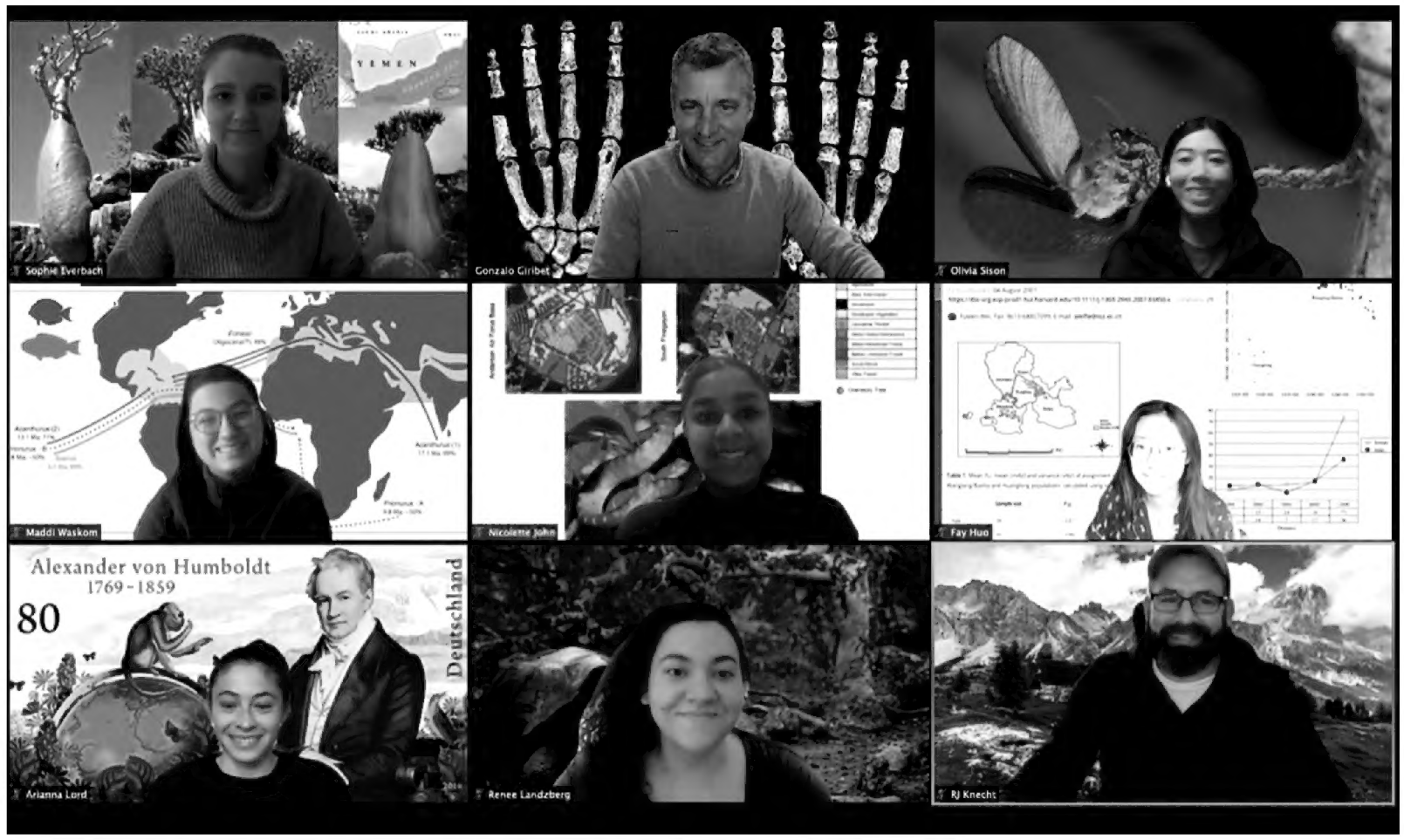
OEB 141: Biogeography

Gonzalo Giribet

Explains distributions of organisms through historical and ecological factors, focusing on the history of biogeographic research, developments in the area of historical biogeography and ecological processes that affect distributions of whole clades.

OEB 150: Exceptional Paleobiological Insights into Animal Evolution

Rudy Lerosey-Aubril



OEB 141: Biogeography

OEB 150: Exceptional Paleobiological Insights into Animal Evolution

Javier Ortega-Hernández

Explores the importance of soft-tissue preservation in the rock record through an overview of major exceptional fossiliferous sites around the world and throughout the Precambrian to Mid-Phanerozoic, with particular emphasis on the evolutionary history of invertebrate animals.

OEB 155R: Biology of Insects

Naomi E. Pierce

An introduction to the major groups of insects. The life history, morphology, physiology and ecology of the main taxa are examined. Topics include the phylogeny of terrestrial arthropods, an analysis of abiotic and biotic factors regulating populations, and the use of insects in biological control.

OEB 207: The Fishy Aspects of the Human Body

Stephanie E. Pierce

Exploration of how the human body evolved through an analysis of the non-fiction book, *Your Inner Fish: A Journey into the 3.5-Billion-Year History of the Human Body*, by evolutionary biologist Neil Shubin.

OEB 213: Evolutionary Convergence, Mass Extinctions and the Shape of Life

Javier Ortega-Hernández

An examination of how processes acting through deep time affect fundamental biodiversity patterns, including topics such as the origin of animals, the rapid diversification of major clades and the impact of extinction.

OEB 130: Biology of Fishes

George Lauder

Freshman Seminar

FRSEMR 22T: Why We Animals Sing

Brian D. Farrell

Investigates the sounds and structures of different kinds of acoustic animals—including birds, mammals, frogs and insects—and the different kinds of habitats in which they produce their songs and calls.

FRSEMR 41U: Museums in the Age of COVID

James Hanken

Traces the history of museums from their beginnings centuries ago as personal collections maintained by private (wealthy) individuals to the modern institutions of today, with an emphasis on challenges brought on by the COVID-19 pandemic.

FRSEMR 50H: The Biology of Movement

Andrew A. Biewener

Explores why and how organisms move, providing an overview of the biological motors animals and microbes use to power movement and the mechanisms plants use for growth and geotaxis and phototaxis, as well as the aesthetics and health benefits of movement.

Life Sciences

LIFESCI 2: Evolutionary Human Physiology and Anatomy

Andrew Biewener, George V. Lauder (and Daniel E. Lieberman)

Explores human anatomy and physiology from an integrated framework, combining functional, comparative and evolutionary perspectives on how organisms work.

Graduate Courses of Reading and Research

OEB 275R: Phylogenetics and Phylogeography in the Era of Genomics

Scott V. Edwards

OEB 306: Invertebrate Paleobiology and Evolution

Javier Ortega-Hernández

OEB 307: Biomechanics, Physiology and Musculoskeletal Biology

Andrew A. Biewener

OEB 310: Metazoan Systematics

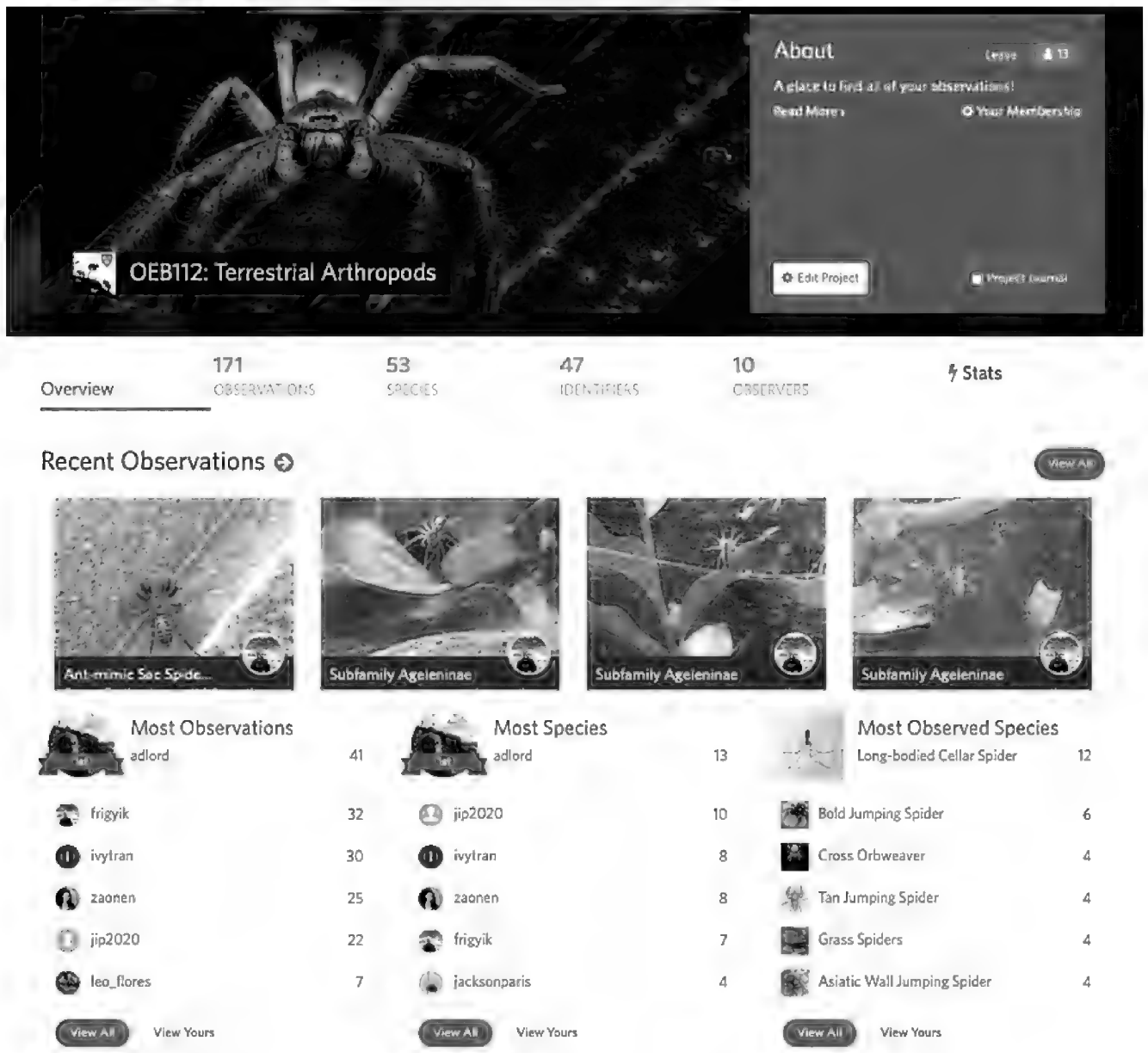
Gonzalo Giribet

OEB 320: Biomechanics and Evolution of Vertebrates

George V. Lauder

OEB 321: Evolution of Regeneration and Development

Mansi Srivastava



OEB 112: Arthropod Biology: Arachnids and Myriapods, Their Biology and Evolution

OEB 323: Advanced Vertebrate Anatomy

Stephanie E. Pierce

OEB 334: Behavioral Ecology

Naomi E. Pierce

OEB 341: Coevolution

Brian D. Farrell

OEB 355: Evolutionary Developmental Biology

James Hanken

OEB 362: Research in Molecular Evolution

Scott V. Edwards

OEB 370: Mammalian Evolutionary Genetics

Hopi Hoekstra

OEB 399: Topics in Organismic and Evolutionary Biology

Scott V. Edwards

OEB 155R: Biology of Insects

Highlights of Faculty-Curator Grants

In addition to their teaching responsibilities, curatorial duties and research efforts, MCZ faculty-curators obtain grants for and lead long-range, often multi-institutional research projects.

"Faculty-curator grants constitute the basis for a large component of the research happening in the MCZ," says Director Giribet. "They showcase the cutting-edge nature of the work our faculty-curators and their students and postdocs undertake. The competitive grants highlighted here are examples of such diverse research on animal genomics, development, paleoecology and animal-inspired robotics."

Scott V. Edwards is the Principal Investigator for "Statistical and High-throughput Models of Enhancer Function and Evolution," a four-year research grant from the National Institutes of Health/National Himan Genome Research Institute for $2,246,451. Enhancers regulate gene expression and play an important role in modulating diverse phenotypes—the traits of an organism, such as its physical form, developmental processes, behavior, biochemical and physiological processes—and disease states. The grant supports the development of statistical models that allow researchers to connect evolutionary changes in enhancer sequences within and between species (comparative population genomics) to phenotypic variation. The project will also functionally test diverse enhancers on a large scale, using the development of forelimbs and hind limbs of flying and flightless birds as a model of development and gene expression. The result will be a number of tools that will benefit the research community using comparative genomics to understand links between genotype and phenotype.

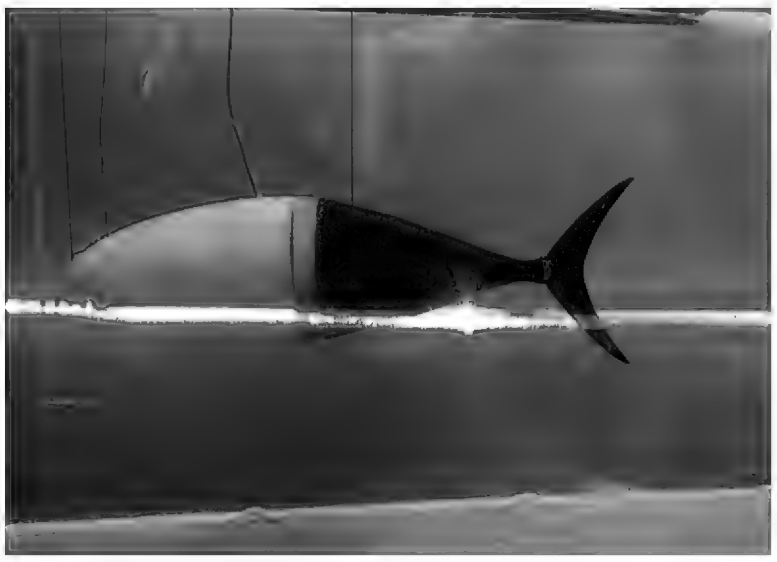
Javier Ortega-Hernández is the Principal Investigator for the CAREER Grant "Ecological Turnover at the Dawn of the Great Ordovician Biodiversification Event—Quantifying the Cambro-Ordovician Transition through the Lens of Exceptional Preservation," a five-year $829,539 grant from the National Science Foundation. The Great Ordovician Biodiversification Event represents a sequence of large evolutionary radiations of marine organisms lasting over 30 million years that established the basic composition and ecological dynamics of the modern marine biosphere. Our understanding of this major event remains fragmentary because the fossil record excludes the majority of species in marine communities that are made up of soft tissues, such as many invertebrates. The project aims to produce a more complete view of biodiversity during the Lower Ordovician through the systematic description of new fossils with exceptional soft-tissue preservation from the Fezouata biota of Morocco to produce the first high-resolution reconstruction of the community structure and ecology of a post-Cambrian marine deposit. The grant will make it possible to involve postdoctoral, graduate and undergraduate researchers and develop an augmented reality exhibition at the Harvard Museum of Natural History.

Javier Ortega-Hernández

Javier Ortega-Hernández

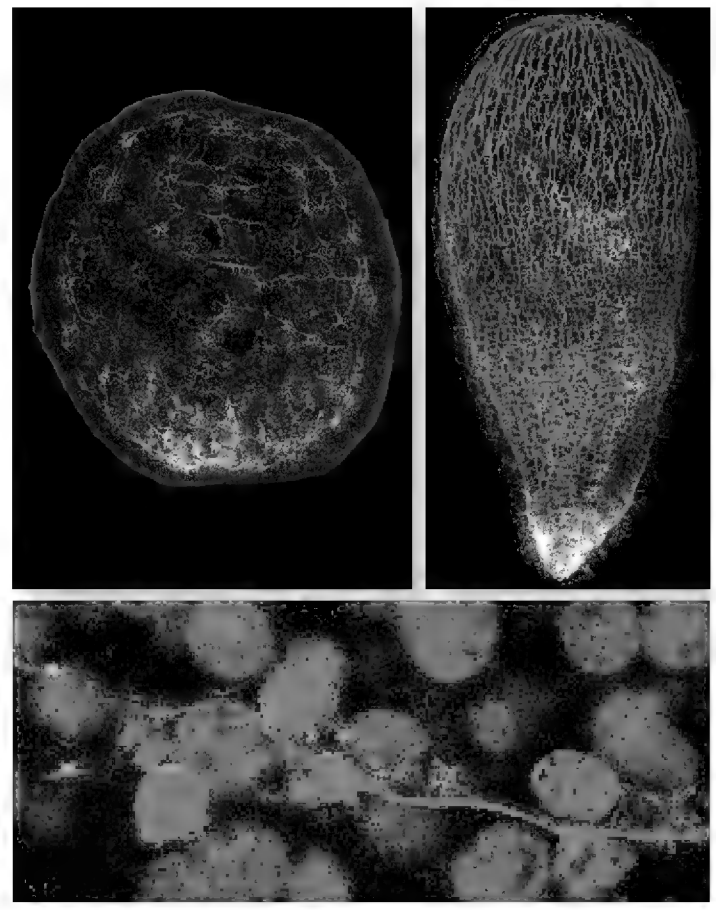
Heavily pyritized carapace of an unnamed marrellomorph arthropod from the Fezouata biota. At right, filter feeding apparatus of the giant swimming arthropod ancestor *Aegirocassis*, one of the largest invertebrates to ever live.

George V. Lauder is the Principal Investigator for "Bio-inspired Flexible Propulsors for Fast, Efficient Swimming: What Physics Are We Missing?" The one-year $140,743 grant from the Office of Naval Research will study the locomotor performance of live fishes (brook trout) swimming in the Lauder lab's flow tank. There will also be collaborative experiments with the robotic tuna platform developed by the lead Principal Investigators at the University of Virginia. UVA will provide the latest robots for testing in the Lauder lab flow tanks to measure body kinematics and fluid flow patterns over the robotic tuna as they swim at a variety of speeds.



George Lauder

Mansi Srivastava is the Principal Investigator for "Comparing Development and Regeneration to Uncover Mechanisms for Maintaining Regenerative Ability in Adult Animals," a two-year $300,000 grant from the Richard and Susan Smith Family Foundation. The long-term goal of this work is to obtain a mechanistic understanding of how pluripotent (undifferentiated) stem cells made in early embryos can be maintained into adulthood by using a new research organism, the acoel *Hofstenia miamia*, which can regenerate any missing cell type and in which both adult animals and early embryos have pluripotent cells. This project will ask two questions about how development and regeneration work in *H. miamia*: how genes involved in regeneration in adults operate and control each other during development, and how the genomes of cells in adult animals are maintained in undifferentiated/pluripotent states. The project will reveal genetic pathways that can be used to maintain pluripotent cells into adulthood, which can inform the development of new applications in human regenerative medicine.



Katy Loubet-Senear

Hofstenia miamia

Aaron Hartmann, a research associate in the Giribet lab, is the Principal Investigator for the Belmont Forum Collaborative Research Action "ARMS to Reefs: A New Tool to Restore Coral Reef Biodiversity, Fisheries Yields and Human Health in Madagascar," a three-year $399,293 grant from the National Science Foundation. Coral reefs are one of the most valuable ecosystems on the planet, providing food, income and shoreline protection, and they are being lost at an alarming rate due to human activities. The project's goal is to rebuild healthy coral reef ecosystems and increase fisheries catch in Madagascar. Researchers will build artificial reefs and seed them with biota from healthy coral reefs by repurposing a biodiversity census tool called Autonomous Reef Monitoring Structures (ARMS) to transfer organisms that generate habitat, provide ecosystem services and are otherwise challenging to collect and move, such as sponges, larvae and bacteria, from healthy natural reefs to artificial reefs. Researchers will apply cutting-edge tools, including environmental DNA barcoding, fisher-supported GPS tracking of fisheries activities, and extensive human health and well-being data collection to comprehensively connect ecosystem health to human health.

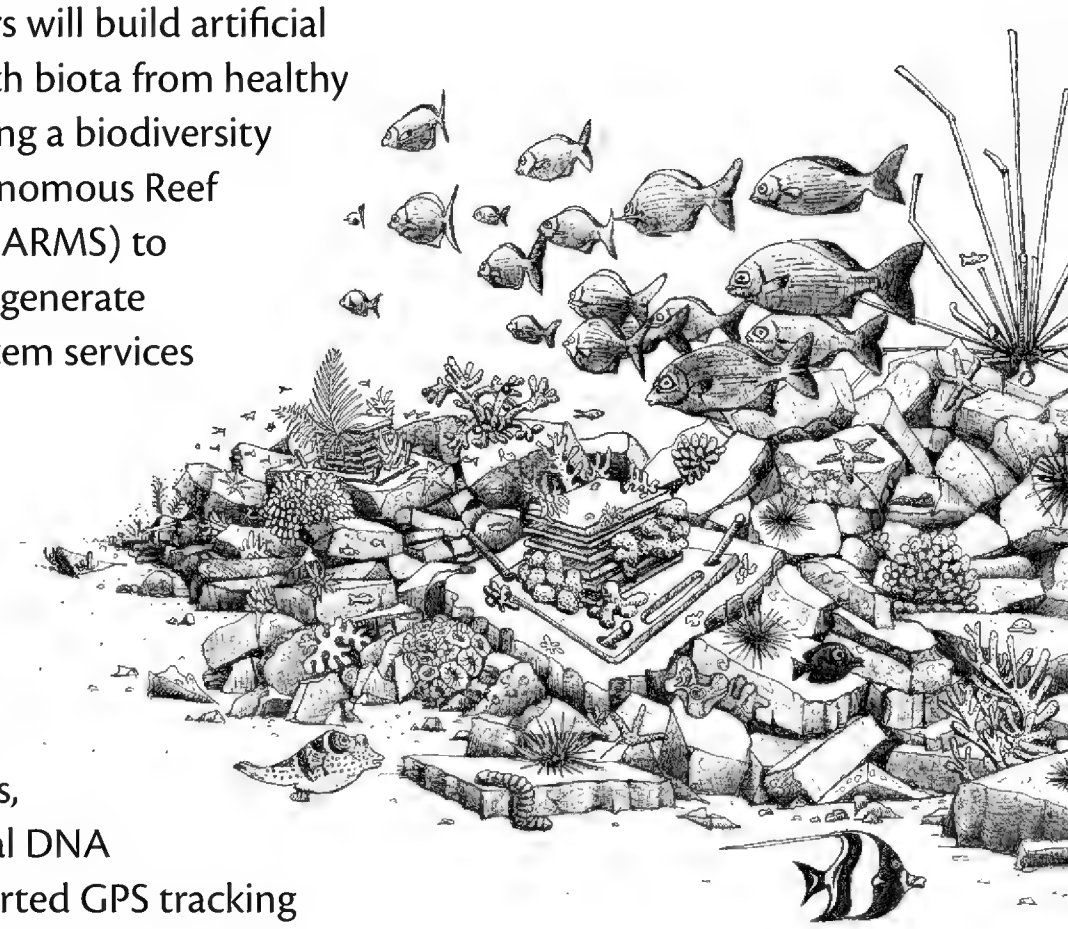


Illustration of an ARMS unit and a populated reef, by Ben Darby

Research Making Headlines

Ready for Takeoff

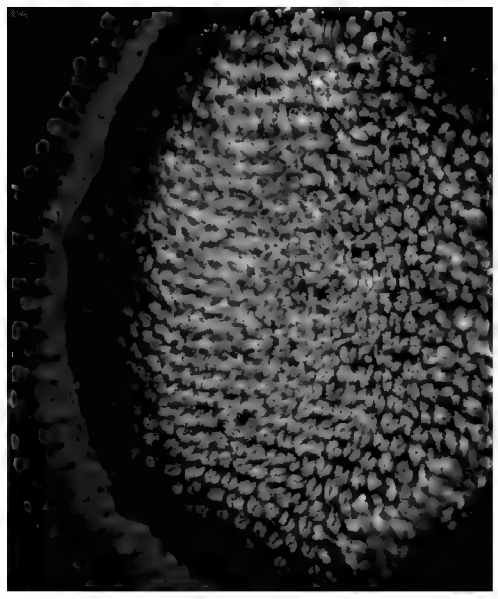
Roy & Marie Battell

Mallard ducks have the ability to launch themselves into the air almost vertically, a feat even more impressive when one considers that they take off from both land and water environments. While waterfowl use a combination of forces generated by their feet, legs, wings and tail to achieve liftoff, **Kari Taylor-Burt** and **Andrew A. Biewener** focused their investigation on the hindlimb, hypothesizing that the feet must paddle faster during aquatic takeoffs to compensate for the drag of the water, but in terrestrial takeoffs, the hindlimb must generate greater muscle forces to achieve liftoff.

To test their hypothesis, the researchers trained a group of farm-raised and wild-caught mallard ducks to take off in a flight arena—a long hall with high ceilings—from both land and water. Once the ducks were trained, they recorded takeoffs from both environments with high-speed light video and X-ray video and performed 2- and 3-D kinematics analysis to examine the motion of the hindlimb and contraction of the lateral gastrocnemius (LG), a major ankle extensor and knee flexor—analogous to the human calf muscle—that powers foot motion. In contrast to their hypothesis, they found that there was no change in the ankle in either type of takeoff, but there were changes in the angle of the knee's motion. In a water launch, power comes from a flex in the knees that allows the knee and ankle joints to work together to enhance foot motion and LG muscle output. But in a land launch, the knees extend and the hips and joints in the foot generate greater force to lift the bird into the air.

Taylor-Burt KR, Biewener AA (2020) Aquatic and terrestrial takeoffs require different hindlimb kinematics and muscle function in mallard ducks. *J Exp Biol* 223:jeb.223743 DOI: 10.1242/jeb.223743

In the Eye of a Butterfly



Marjorie Liénard

Nanfang Yu

Insects' ability to perceive colors is critical for behaviors from feeding to mating. These visual abilities are derived from genes that code for light-sensitive opsin proteins in the eyes, but tools to investigate the functional aspects of those proteins to determine what insects actually see have been limited—until now.

In a four-year study, postdoctoral researcher **Marjorie Liénard**, **Naomi E. Pierce**, and a multidisciplinary team of researchers that included Harvard professors, postdoctoral fellows, graduate students and undergraduates, among others, developed a novel method to isolate long-wavelength opsins outside of an organism and test their function in cell cultures.

Working with the atala hairstreak butterfly, *Eumaeus atala*, and the Japanese oak blue, *Arhopala japonica*, to investigate red-sensitive receptors, the team discovered a previously unknown opsin that evolved from detecting the color green to perceiving the longer wavelength of red light. They then found that another opsin, duplicated from one that typically detects blue, was spectrally tuned by a few amino acid changes to recognize green light. This increased visual range indicates a robust ability to detect color differences across an extended range of wavelengths, thereby allowing efficient detection of members of the same species and host plants.

Because insects are invertebrates, and invertebrates share the same type of opsin receptors, the researchers are reasonably confident that these tools can be used to study the visual systems of all invertebrates, including insects, crustaceans, mollusks and spiders, and thus begin to trace the evolutionary changes in visual systems across invertebrate lineages.

Liénard MA, Bernard GD, Allen A, Lassance J-M, Song S, Childers RR, Yu N, Ye D, Stephenson A, Valencia-Montoya WA, Salzman S, Whitaker MRL, Calonje M, Zhang F, Pierce NE (2021) The evolution of red color vision is linked to coordinated rhodopsin tuning in lycaenid butterflies. *Proc Natl Acad Sci USA* 118:e2008986118 DOI: 10.1073/pnas.2008986118

Conquering a New Landscape

The earliest tetrapods—four-legged vertebrates—evolved from ancient fish around 390 million years ago. There have been many theories about how and where early tetrapods used their limbs, but since soft tissue like muscle is often not preserved in the fossil record, little consensus has been achieved.

To examine the possible gaits of early tetrapods, **Stephanie E. Pierce** and colleagues spent years working to understand the musculature of early tetrapods. Based on this research, the team built 3D musculoskeletal models using the pectoral fin of *Eusthenopteron*, an extinct fish closely related to tetrapods, and the forelimbs of the early tetrapods *Acanthostega* and *Pederpes*. For comparison with modern organisms, they also modeled pectoral fins of a coelacanth and lungfish and forelimbs of a salamander and lizard. The researchers were then able to manipulate the models to measure the range of motion of the joints and the ability of the muscles to move the fins or limbs. The team determined that the forelimbs of tetrapods evolved in specific stages: first, a "benthic fish" stage similar to a modern lungfish where fins were possibly used for propping the body on a substrate; then an "early tetrapod" stage with its own cluster of characteristics unlike any extinct or modern animal; and finally a "crown tetrapod" stage with gaits similar to lizards and salamanders. The results showed that the forelimb musculoskeletal system of early tetrapods was more adapted for pushing back and forth against a substrate than bearing their body weight. This indicates that early tetrapods used unique locomotor behaviors to navigate their amphibious habitat and that enhanced abilities to support their body on land appeared somewhat later in tetrapod evolution.

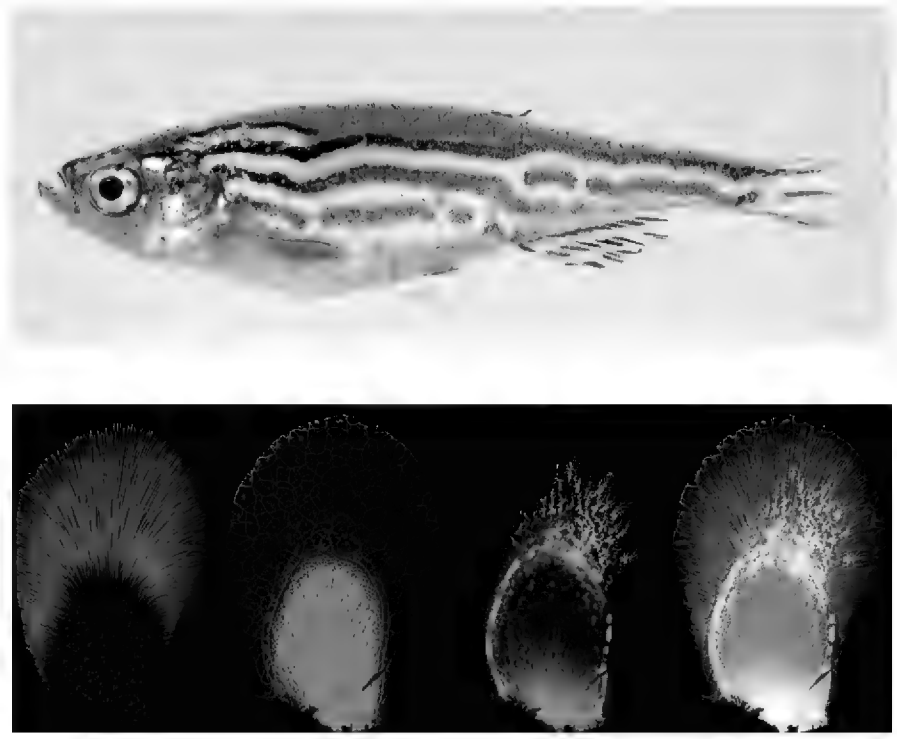
Molnar JL, Hutchinson JR, Diogo R, Clack JA, Pierce SE (2021) Evolution of forelimb musculoskeletal function across the fish-to-tetrapod transition. *Sci Adv* 7:eabd7457 DOI: 10.1126/sciadv.abd7457

Early tetrapods *Ichthyostega* and *Acanthostega*. Illustration © Davide Bona

Out on a Limb

To study the fin-to-limb transition, a team led by **M. Brent Hawkins** in the Hanken lab took a novel molecular approach. These researchers manipulated zebrafish, a popular model organism to study development, to generate random changes in the DNA and looked for mutations that reshaped the simple structure of its pectoral fin. The zebrafish is part of a diverse group known as teleost fishes, and in teleosts the pectoral fin is remarkably consistent; it has a ray-like pattern of bones attached directly to the body, with no joints or direct attachment of muscle to the bone. When the researchers found mutants that added novel bones to the fin in an articulated manner with joints, they used CRISPR technology to uncover the genes responsible for the change: *waslb* and *vav2*, which cause an increase in the expression of the gene *hoxa11b*, which is required to make the bones of the forearm. Microscopic study of the mutant tissues further revealed that the new bones were fully integrated into the fin and also had muscle attachment.

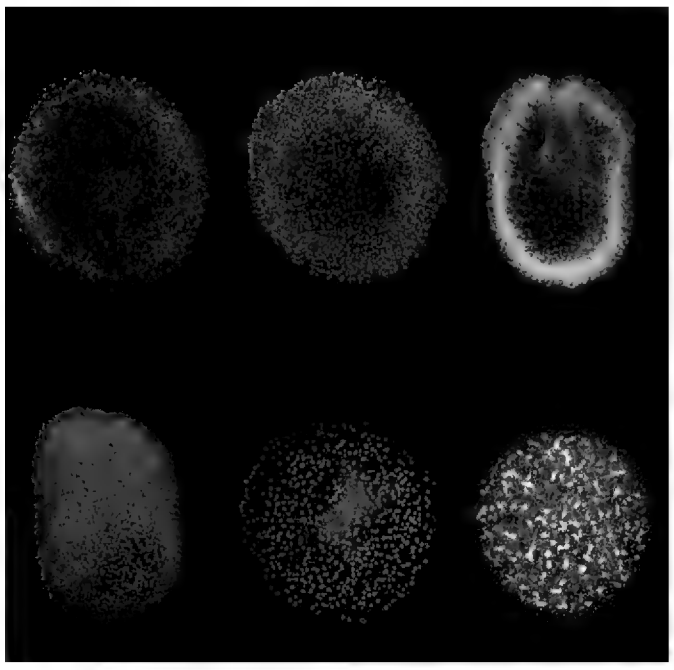
Previous genetic studies of limb development identified mutations that make limbs simpler, but this is the first known research to take a gene, turn it up, and get a more complex structure as a result. This research shows that the Hox code for creating limbs was likely present in the common ancestor of teleost fishes and the tetrapods, the group of four-legged animals of which humans are part. This developmental potential was refined in the evolution of lobe-finned fishes during their transition to land and surprisingly has been retained in living teleosts like the zebrafish.



M. Brent Hawkins (2)

Hawkins MB, Henke K, Harris MP (2021) Latent developmental potential to form limb-like skeletal structures in zebrafish. *Cell* 184:899-911.e13 DOI: 10.1016/j.cell.2021.01.003

Finding the Keys to Regeneration



Julian Kimura

Mansi Srivastava and her research team are working to uncover the molecular and cellular mechanisms underlying whole-body regeneration by studying the three-banded panther worm, *Hofstenia miamia*, an animal so adept at regenerating itself that it can replace any missing cell type and reestablish its entire body, even when cut in half.

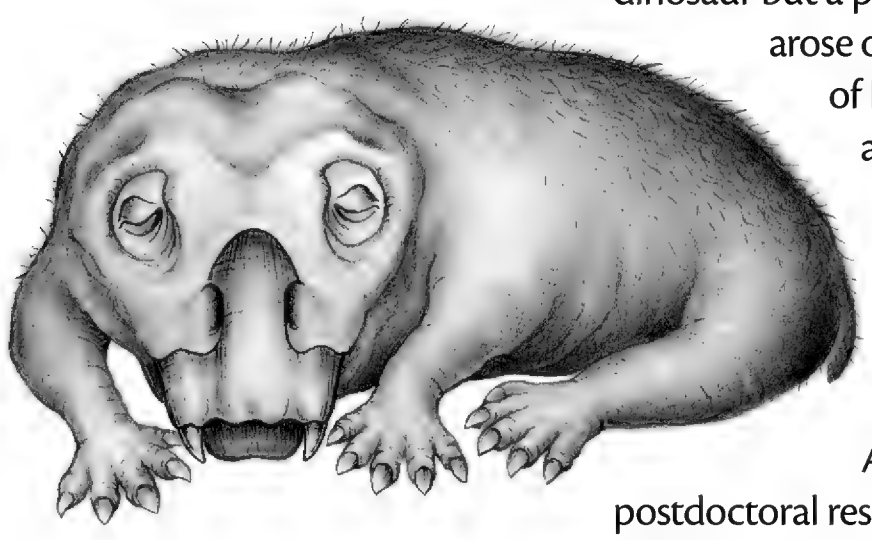
Hofstenia miamia is a bilaterian, meaning it has a symmetrical body plan with distinct head-to-tail and back-to-belly orientations. To understand how it regenerates its body correctly along these axes, Prof. Srivastava, **Alyson Ramirez** and **Katy Loubet-Senear** investigated the molecular mechanisms that launch Wnt signaling, which is used in many animals to regenerate tissues along the primary axes. The researchers established a gene regulatory network for initiating Wnt signaling in posterior-facing wound tissues in *H. miamia*, thereby illuminating how the animal, when cut across the middle, can regenerate the tail and not, say, a second head.

The origin of bilateral symmetry around 550 million years ago was a major transition in animal evolution that coincided with the evolution of organized nervous systems oriented along the major body axes. In a separate study, Prof. Srivastava, **Ryan Hulett** and **Dierdre Potter** characterized the neural anatomy of *H. miamia*. They found that the *H. miamia* genome encodes a full complement of enzymes for the major neurotransmitter pathways, determined that the animal has an organized nervous system with a complex concentration in the head, and established a detailed timeline for robust regeneration of the nervous system. This work will enable studies of neural regeneration and inform our understanding of the evolution of nervous systems.

Ramirez AN, Loubet-Senear K, Srivastava M (2020) A regulatory program for initiation of Wnt signaling during posterior regeneration. *Cell Rep* 32:108098 DOI: 10.1016/j.celrep.2020.108098

Hulett RE, Potter D, Srivastava M (2020) Neural architecture and regeneration in the acoel *Hofstenia miamia*. *Proc R Soc B* 287:20201198 **DOI: 10.1098/rspb.2020.1198**

A Long Winter's Nap



Crystal Shin

Despite its name, *Lystrosaurus* was not a dinosaur but a precursor to mammals that arose on the single supercontinent of Pangea 250 million years ago. It survived the turbulent times of the Permo-Triassic mass extinction, becoming so successful that its fossils have been found in China, Russia, India, Africa and Antarctica. **Megan R. Whitney,** postdoctoral researcher in the S. Pierce Lab, and collaborator Christian Sidor may have found clues to this success—signs that it may have been warm-blooded and polar populations used a hibernation-like metabolic slowdown to survive periods of limited resources.

Lystrosaurus grew to 6 to 8 feet long and had a turtle-like beak with two small tusks, which grew throughout the life of the animal. Much like elephants and other mammals whose tusks grow for their entire lifetimes, the dentine of *Lystrosaurus* tusks was deposited in concentric rings that can provide a record of the animal's physiology. To study these rings in *Lystrosaurus*, the researchers used cross-sections of fossilized tusks from Antarctica and South Africa. In the Triassic, the area of Pangea within the Antarctic Circle was more temperate, but had extreme periods of darkness that limited the availability of food, while the South African area was 550 miles farther north and outside the Antarctic Circle.

The tusks from both locations showed similar growth patterns, but the researchers found stacks of thick dark rings only in the Antarctic samples. These "stress rings" could indicate that the animal's metabolism slowed down to levels akin to hibernation and also imply that the animal periodically roused itself, much like modern warm-blooded mammals during hibernation.

Whitney MR, Sidor CA (2020) Evidence of torpor in the tusks of *Lystrosaurus* from the Early Triassic of Antarctica. *Comm Biol* 3:471 **DOI: 10.1038/s42003-020-01207-6**

Highlights from the Collections

New Acquisition of Exceptionally Preserved Fossils

While most of the fossil record is made up of bones and teeth, a few unusual sites around the world offer a glimpse into ancient creatures without them. One of these sites, in Morocco, is the Fezouata biota, the most diverse and abundant Ordovician deposit with soft-tissue preservation. "Working with Moroccan colleagues, the MCZ has acquired six tons of rock containing these exceptionally preserved fossils," says **Javier Ortega-Hernández**, curator in Invertebrate Paleontology. "A consortium of organizations with similar large collections, including Yale and the University of Switzerland in Lausanne, will be conducting joint research on the material with Moroccan colleagues."

Javier Ortega-Hernández

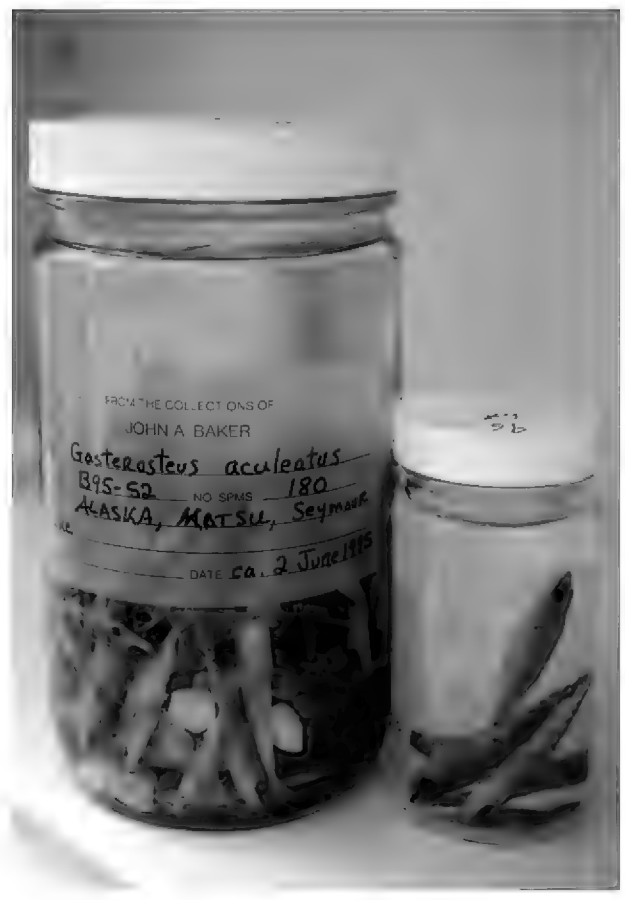
Javier Ortega-Hernández

The fossils get their bright orange color from pyritization, a process in which iron-rich pyrite either covers or fills the voids left by the soft tissue. These fossils will help advance understanding of the Great Ordovician Biodiversification Event, a sequence of large evolutionary radiations of marine organisms lasting over 30 million years that established the basic composition and ecological dynamics of the modern marine biosphere.

In the fall semester of 2021, the material will be undergoing collection work to catalog and house the fossil-rich rock, and full research will begin after that. Prof. Ortega-Hernández is the Principal Investigator in a five-year CAREER Grant from the National Science Foundation that will support the research; create a website to house and serve the data in English, French and Arabic; and present these unique fossils and the research findings to the public in an augmented reality exhibition at the Harvard Museum of Natural History.

The Foster–Baker Stickleback Collection

Sticklebacks have become a model organism in the field of evolutionary biology, and a significant collection of sticklebacks now has a new home at the MCZ. Drs. John Baker and Susan Foster, their colleagues, and students at Clark University collected the specimens between 1983 and 2020, mostly in Alaska. The collection contains over 1,700 lots with roughly 295,000 specimens, and robust accompanying field notes contain exacting data about the habitats in which each lot was collected.



Melissa Aja

The collection is composed almost completely of three-spine sticklebacks (*Gasterosteus aculeatus*), a species ranging from only 1 to 3 inches in length but playing a major role in behavioral and evolutionary biology. According to **Andrew Williston**, curatorial associate in Ichthyology, "Sticklebacks live in a really wide range of habitats and show dramatic variations between those habitats. Because of that, it's allowed researchers to ask some very specific questions as far as how environment affects development and the evolution of the species."

Specimens are fluid preserved and serve both as vouchers for work already done by the Foster–Baker Lab at Clark University and as an immediate resource of research material to the greater scientific community. "I think it's a great example of a collection treasure held by one single lab for 20 years and then nearly orphaned," says Williston. "Now that it is here at the MCZ, it's more open to research and can fuel a lot of ideas and projects."

Staff Highlight

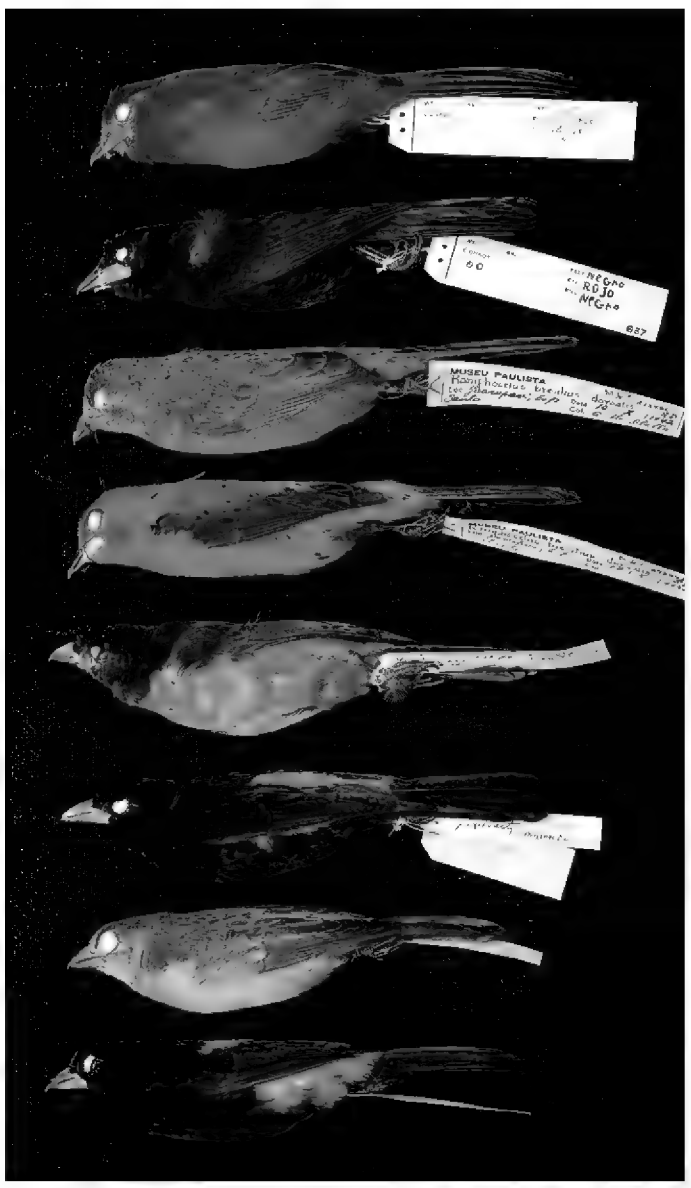
Melissa Aja

Christina Byrd joined the MCZ as the curatorial associate in Vertebrate Paleontology in January 2020, not long before the pandemic shutdown. She moved from Hays, Kansas, where she was the Paleontology Collections Manager at Fort Hays State University's Sternberg Museum of Natural History.

At the age of eight, watching a PBS documentary about the La Brea Tar Pits, she first learned that you could make a living studying ancient animals. So she went to the computer, looked up paleontology and began planning for what she'd need to learn to get into the field. To be a paleontologist, she needed a strong background in geology and biology, so she earned her undergraduate degree in geology at the College of William and Mary and her graduate degree in biology at Marshall University. This academic combination has served her well.

Byrd manages approximately 90,000 fossil specimens, a large vertebrate paleontology collection by museum standards. "My objective is to be the best steward of the collection that I can be, ensuring that the specimens entrusted to me are physically cared for—cleaning, repairing damage, conserving associated documents and photos, creating proper housings—and ensuring the catalog information is as accurate as possible," she says. Some of the fossils were collected as far back as the 1820s, and she is fascinated by the detective work that goes into piecing together the documentation and history for these oldest specimens. "But there's also the digital representations of the fossils—CT scans, X-rays, photographs, 3D models—and these digital objects in the collection require equal conservation care as the physical specimens."

Notably, she is also the steward of the *Kronosaurus queenslandicus*, mascot of the MCZ. "No pressure there," she laughs.



Jeremiah Trimble

Brilliant Birds

Why have some birds evolved to be so brilliantly colored? The predominant theory is that color may indicate the fitness of an individual bird, called "honest signaling theory," and, as an indication of health, assists the female in choosing the most desirable mate. Red, orange and yellow carotenoid-colored birds are a textbook example of this theory, but the full physical basis of color in males compared to females is not fully understood.

Allison Shultz and colleagues were interested in investigating the evolutionary "why" behind brilliantly colored birds by studying the physical mechanisms of color (pigments and structures) and the evolutionary mechanisms that favor colorful signals over time (selective pressures). To obtain the subjects for their study, they reached out to **Jeremiah Trimble**, curatorial associate in Ornithology, and **Kate Eldridge**, curatorial assistant, for help in selecting appropriate samples of *Ramphocelus* tanagers. They chose 20 intact male and female specimens obtained during the same collecting trips. Analyzing the feathers from the specimens, the researchers found that males, but not females, have diverse and elaborate feather microstructure. They hypothesize that honest signals can be gamed, which they termed "the proxy treadmill," in which males, under intense selection pressures to satisfy picky females, evolve microstructure "amplifiers" to honest signals.

"The Ornithology collection was excited to assist in this study," says Trimble. "The use of our physical specimens in this way aligns with our goal to support novel and innovative research and highlights how the valuable specimens held at the MCZ can be utilized to expand our knowledge of the natural world."

McCoy DE, Shultz AJ, Vidoudez C, van der Heide E, Dall JE, Trauger SA, Haig D (2021) Microstructures amplify carotenoid plumage signals in tanagers. *Sci Rep* 11:8582 DOI: 10.1038/s41598-021-88106-w

Projects & Initiatives

Ernst Mayr Library

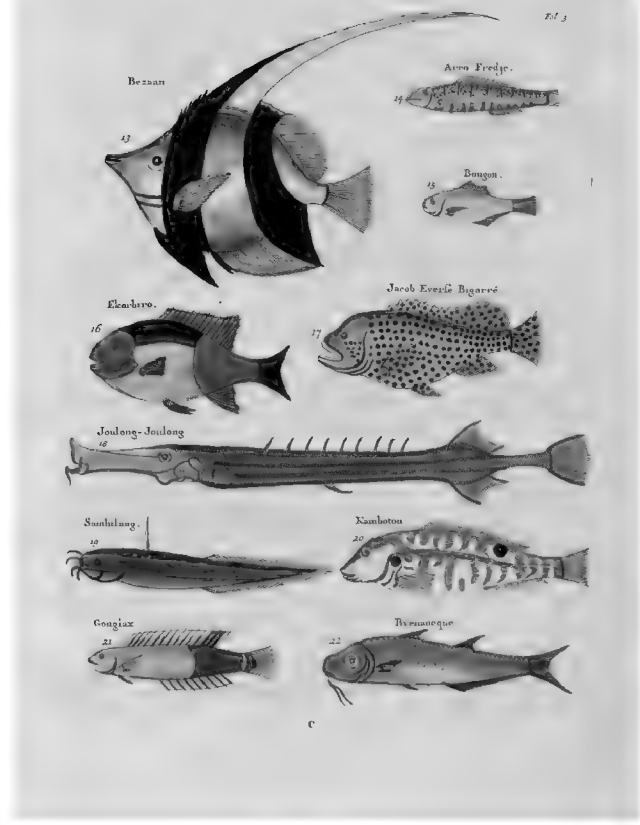
The EML supports both the people and collections of the MCZ and the educational mission of the University by sharing print collections, archives and digital assets.

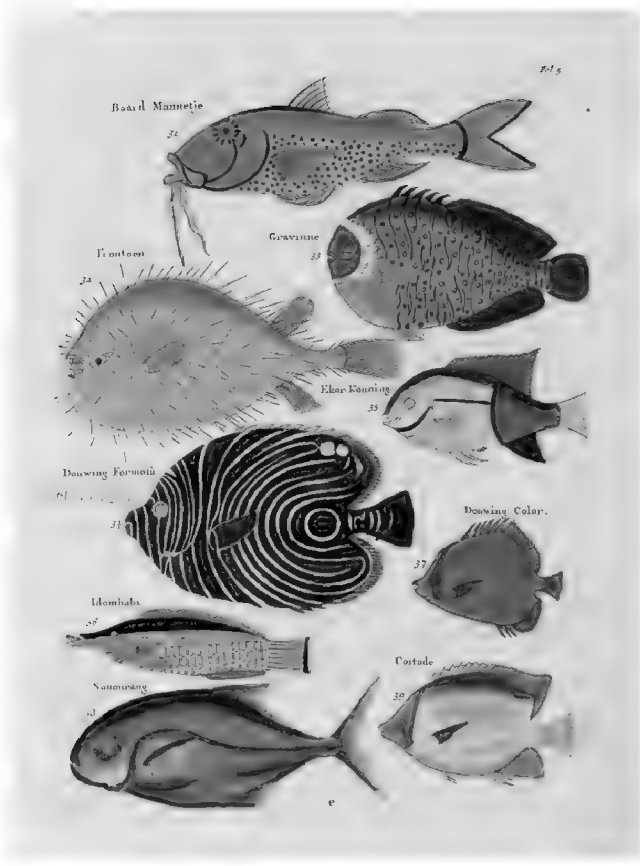
Connie Rinaldo

At the end of December, Director Connie Rinaldo retired after more than 20 years of leadership. She accomplished many important things as head librarian: modernizing the EML by introducing electronic circulation, barcoding materials and adding an enhanced security system at the library entrance; facilitating linkages among digitized archival collections, published literature, and museum specimen data with the overall goal of discovery and accessibility; positioning the library as a founding member of the **Biodiversity Heritage Library** by leading digitization grants and serving on the BHL executive committee; and, while supporting the use of the EML digital collections by researchers around the world, ensuring that local, in-person users were welcome, comfortable and supported while conducting research in the library. Amy Van Epps, Director of Sciences and Engineering Services, Cabot Science Library, Harvard University, is the acting director of the EML.

During the pandemic closure, faculty, researchers and curatorial staff relied on EML's participation in the Biodiversity Heritage Library to access material that had been digitized in the past. EML continues to work to enhance BHL's online content while focusing on digitizing the unique collections held by the EML and the MCZ.

Over the last year, 117 volumes totaling 5,002 pages were added to BHL. The average number of users and views increased, highlighting the value of these digital resources in helping to maintain research endeavors during the pandemic when print materials were inaccessible. The most-viewed resources during the year include *Poissons, ecrevisses et crabes, de diverses couleurs et figures extraordinaires, que l'on trouve autour des isles Moluques et sur les côtes des terres Australes* (1754) and *Cynipid galls of the Eastern United States* (1959), along with all-time most-popular items *Zoological sketches, v.1* (1861) and the *Journal des Museum Godeffroy* (1873–1875). In addition, more than 4,000 digitized pages of handwritten MCZ archives were transcribed, making them easier to read and search, in a collaborative effort among staff at EML and other Harvard libraries, all working remotely.





Plates from *Poissons, ecrevisses et crabes*, above, and *Zoological sketches*, at left

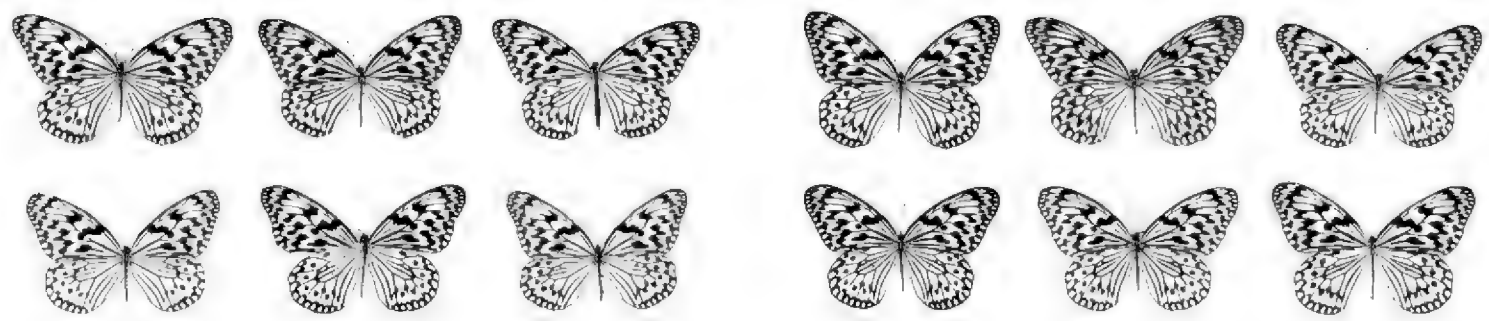
Harvard Museums of Science & Culture

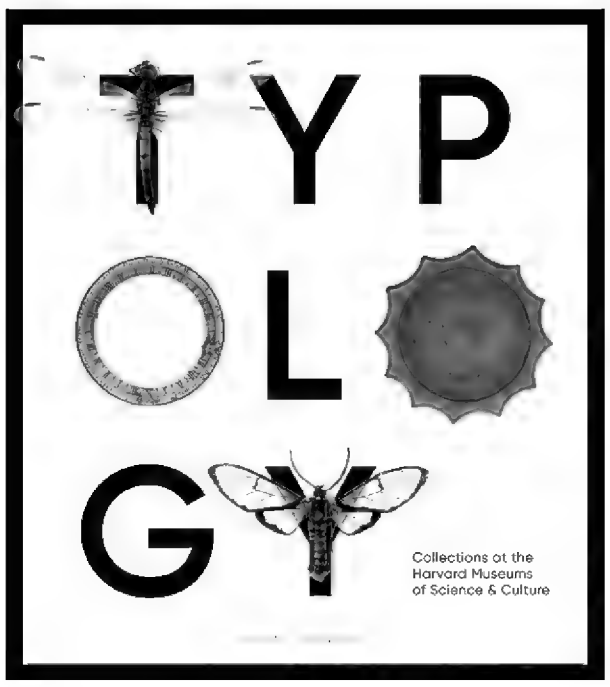
Brenda D. Tindal

In May 2021, Brenda D. Tindal assumed the position of executive director of the Harvard Museums of Science & Culture. As executive director of HMSC, Tindal will lead as the public face of the Faculty of Arts and Sciences research museums.

Tindall comes to Harvard from the International African American Museum in Charleston, S.C., where she served as founding director of education and engagement. Tindal previously held positions at the Levine Museum of the New South and the Detroit Historical Society.

In an interview with the Harvard Gazette, Tindal said, "Museums are not merely cabinets of curiosity; they are well-positioned to serve as hubs for new learning and play a meaningful role in helping their communities and stakeholders grapple with hard truths and nuanced issues."





Typology: Collections at the Harvard Museums of Science & Culture

Gathered during the course of expeditions, excavations and scientific study, the millions of artifacts and specimens held in the HMSC collections represent Harvard's continuing pursuit of knowledge about our diverse world and its history. In *Typology*, Diana Zlatanovski, collections steward at the Peabody Museum, takes her camera into the museums' storage cabinets to demonstrate that these collections are visually captivating as well.

According to Zlatanovski, assembling similar objects in multitudes, which she calls typologies, compels us to study the details of each singular object and how it differs from the last. Patterns resonate and reveal themselves in this unique photographic essay on the collections, creating intrigue, inspiration and wonder. Zlatanovski discusses her book in the *HMSC Connects!* podcast *Exploring the Power of Objects*.

Women of the Museum Exhibit

The HMSC's online exhibit *Women of the Museum, 1860–1920: Behind-the-Scenes at the Museum of Comparative Zoology* highlights, for the first time, the significant contributions that women made during the Museum's early history. The exhibit features extensive materials from the Ernst Mayr Library Special Collections and Archives of the MCZ.

When women first started working at the MCZ in the late nineteenth century, they were hired as assistants, secretaries and librarians—and only rarely as curators. While their expertise and extensive knowledge of the collections may not have been fully appreciated by their contemporaries, it's now recognized that their work made it possible for the Museum to become a center for research, teaching and public programs.

Through careful research into the roles, lives, working conditions and invisible labor of these women, guest curator Reed Gochberg offers a view of their work preparing collections for public exhibits, cataloging specimens and planning educational offerings and, in doing so, provides an important glimpse into the many people and histories behind individual objects at the Museum.

Ernst Mayr Library & Archives of the MCZ

Elizabeth Hodges Clark, circa 1873; at right, an illustrated plate she created

Confronting Our Past and Moving Forward

Mass Audubon Collection, Museum of American Bird Art

Robert A. Gilbert

Ernst Mayr Library & Archives of the MCZ

Ruth D. Turner

The MCZ is committed to developing programs that will evaluate the racial prejudice and gender inequalities that are part of our past, promoting contemporary solutions and offering new educational and research opportunities in the Museum for people who until now may have felt unwelcome or excluded.

The founder of the MCZ, Louis Agassiz, fostered ideas of racial disparity and inequality that underlie prejudice toward African Americans and other people of color. Tributes to him in our building are painful reminders to many of past injustices and we are working to address them. Our conference room, previously named the Agassiz Room, has been renamed the Robert A. Gilbert Room to honor Gilbert (1869–1942), who has only recently been recognized as one of the earliest natural history photographers in North America while he was working for Cambridge-based ornithologist William Brewster. Gilbert worked alongside Brewster not just as a valet and field guide, but also as a collaborator in writing and developing a process to document natural history with photography, a novel idea at the time.

The Ruth D. Turner Oceanography Room honors Turner (1914–2000), a marine biologist specializing in wood-boring bivalves and a pioneer deep-sea biologist. An established biologist in the 1970s, she was one of the first female tenured professors at Harvard and was the first woman to travel in the Woods Hole Oceanographic Institution's deep-sea submarine, ALVIN. She became Curator of Malacology at the MCZ late in her career and spent her emeritus years at Harvard encouraging and mentoring students and colleagues. In 1996, she was named Woman Pioneer in Oceanography by Woods Hole Oceanographic Institution.

MCZ History

One of the most notable field explorers and naturalists to work in the MCZ was Philip Jackson Darlington Jr. (1904–1983), one of the fathers of modern biogeography. As E.O. Wilson superbly put it in the National Academy of Sciences' *Biographical Memoirs*, "Darlington's collecting ability was legendary, as were his quiet toughness and determination in the field." Our own database, with more than 12,000 records attributed to Darlington, can attest to this.

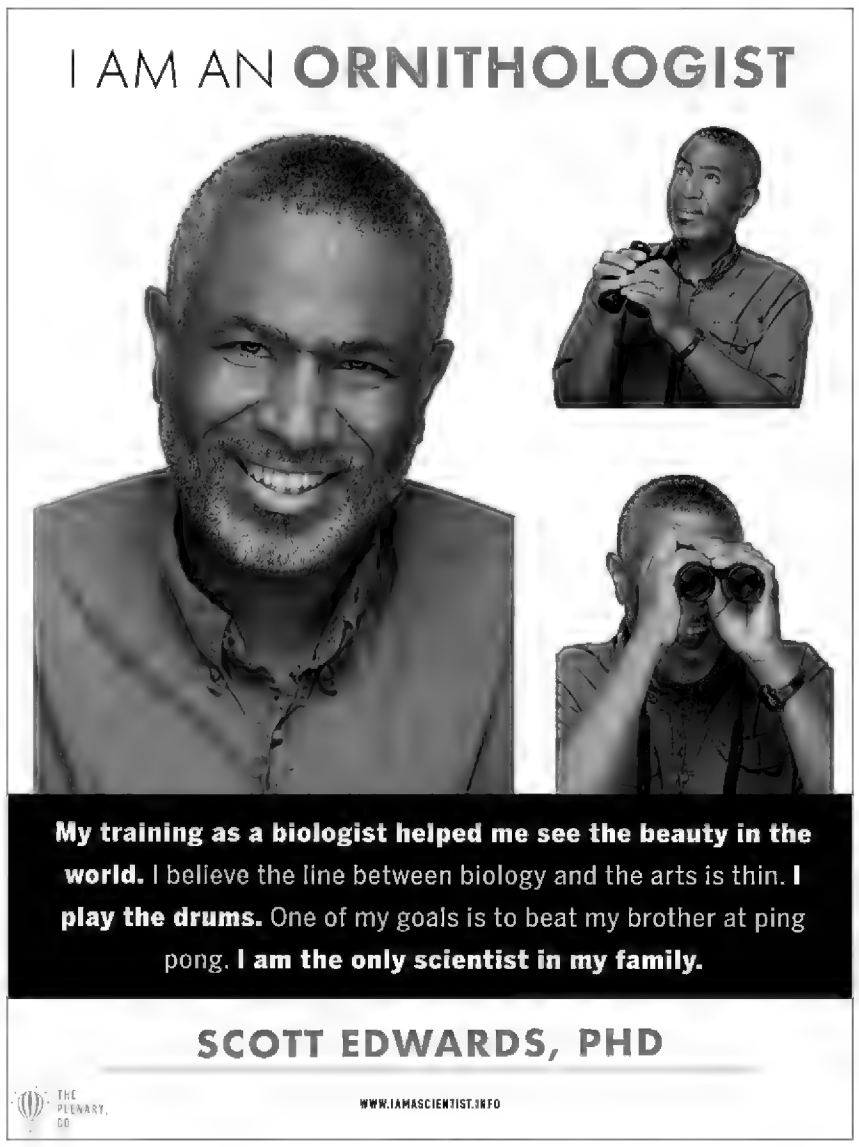
Ernst Mayr Library & Archives of the MCZ

Philip Darlington Jr.

Darlington had his share of incidents during his field expeditions. While he was sampling from water in the middle of a stagnant jungle pond in Papua New Guinea, a giant crocodile weighing hundreds of pounds took the 190-pound intrepid zoologist, spinning him around and dragging him to the bottom of the pond. Somehow, Darlington was able to escape. "Those few seconds seemed hours . . . I kicked, but it was like trying to kick in a sea of molasses. My legs seemed heavy as lead and it was hard to force my muscles to respond." Alone, he hiked to a hospital, the muscles and ligaments of both arms torn and the bones of his right arm crushed. He remained in Papua New Guinea for months, recovering but still working. He developed a new technique using only his left hand to collect and process specimens.

While arguing with Thomas Barbour over how small animals became distributed throughout the Caribbean, Darlington tested his claim that frogs could be dispersed by hurricanes in a most elementary way. A colleague described the "experiment" of dropping live frogs off the fifth floor of the MCZ: "When they had all been dropped, Philip called down to Dr. Barbour asking how they were, to which he replied, 'They're all dead.' But almost immediately the stunned frogs began to recover, and in a few minutes they began to hop about in all directions." While these shenanigans would not be condoned today, they do give us a brief window into the life of Darlington and are part of the MCZ's colorful history.

Awards & Recognition



Faculty-Curators

Scott V. Edwards was featured in the "I Am A Scientist" initiative supporting inclusive STEM education by sharing the stories and science of real-world scientists, and was named one of "1,000 Inspiring Black Scientists in America" by The Community of Scholars.

Javier Ortega-Hernández received a U.S. National Science Foundation CAREER award.

Naomi E. Pierce's research proposal "Prospecting for Functional Materials in the Entomology Collections of the Museum of Comparative Zoology" won a Harvard Climate Change Solutions Fund award.

Stephanie E. Pierce was awarded the William F. Milton Fund for her proposal, "Designing computer simulation techniques to study locomotor evolution in the ancestors of mammals," and the Lemann Brazil Research Fund for "Utilizing Brazil's fossil record to illuminate earth's greatest mass extinction and its link to modern climate change."

Mansi Srivastava was awarded the Smith Family Foundation: Odyssey Award and the Society for Developmental Biology Elizabeth D. Hay New Investigator Award for her work developing the acoel worm, *Hofstenia miamia*, as a model to study whole-body regeneration and uncovering its gene regulatory network.

Edward O. Wilson entered The Library of America Series with two volumes of collected works, joining the 300-plus that are together recognized as America's literary canon.

Postdoctoral Researchers

Vikram Chandra was awarded a Jane Coffin Childs postdoctoral fellowship.

Elsa Goerig received a scholarship from the Fonds de recherche du Québec—Nature et technologies.

Aaron Hartmann received a Certificate of Excellence in Teaching from the Derek Bok Center.

Caroline Hu received an award from the Harvard Brain Science Initiative Young Scientist Transitions Award Program.

Ryan Hulett received a fellowship from the National Institute of General Medical Sciences.

Juan Ignacio Sanguinetti-Scheck received a Human Frontier Science Program postdoctoral fellowship.

Paula Rodríguez Flores was awarded the LinnéSys: Systematics Research Fund by The Linnean Society of London and The Systematics Association.

Tiago R. Simões was awarded a Natural Sciences and Engineering Research Council of Canada Postdoctoral Fellowship.

Graduate Students

Katherine Angier was a recipient of the Harvard Theodore H. Ashford Graduate Fellowships in the Sciences.

Richard Childers, Nicholas Herrmann (2), **Evan Hoki, Richard Knecht, Dave**

Caroline Hu

Matthews, Amber Rock, Sophie MacRae Orzechowski, Wendy Valencia Montoya, Zhengyang Wang, Connor White, Zane Wolf (2), **Brock Wooldridge, Mark Wright** and **Shoyo Sato** each received a Certificate in Distinction in Teaching from the Derek Bok Center.

Richard Knecht received a Harvard Arete Fellowship.

Vanessa Knutson received the American Malacological Society's Constance Boone Award for best student presentation for "Most Cephalaspidea have a shell, but transcriptomes can provide them with a backbone."

Jared Richards received a National Science Foundation Graduate Research Fellowship.

Samantha Royle received a science policy fellowship from the Scientific Citizenship Initiative at Harvard Medical School.

Wendy Valencia Montoya received the Xerces Society for Invertebrate Conservation's Joan Mosenthan DeWind Award.

Undergraduate Students

Ella Frigyik received a Hoopes Prize for her senior thesis "Phylogeographic investigation into the New Zealand harvestman genus *Algidia* (Arachnida: Opiliones: Triaenonychidae)."

Eris Mihelic and **Emory Sabatini** were each awarded a PRISE Fellowship.

Maddi Waskom received an award from the Palaeontological Association Undergraduate Research Bursary.

Staff

We congratulate those that began their retirement this year after many decades at the MCZ: **Stefan Cover**, curatorial assistant in Entomology; **Helene Ferranti**, faculty assistant; **Linda Ford**, director of collections operations; **Laura Leibensperger**, curatorial assistant in Invertebrate Zoology; **Connie Rinaldo**, Ernst Mayr Librarian; and **José Rosado**, curatorial associate in Herpetology.

Melissa Aja

Edward O. Wilson

Jessica Cundiff, curatorial associate in Invertebrate Paleontology; **Tsuyoshi Takahashi**, curatorial assistant in Herpetology and Collection Operations; and **Jonathan Woodward**, curatorial assistant in Collection Operations, celebrated their 20-year anniversaries of working at the MCZ.

Javier Ortega-Hernández

Grant Recipients

Vinícius Costa-Silva

Grants-in-Aid of Undergraduate Research

These grants support research by Harvard College undergraduates under faculty supervision. Priority is given to projects that utilize MCZ research collections, laboratories and facilities. Support for these grants comes from the MCZ's Myvanwy M. and George M. Dick Scholarship for Students.

Emory Sabatini

Gaurab Nandi Das

Lee C. Bryant

Alix Matthews

Recipient	Academic Dept./ Faculty Sponsor	Project Title	Amount
Sorcha Ashe	OEB/Naomi Pierce	Evolution of color perception and signaling in the butterfly tribe Eumaeini (Lycaenidae)	$2,500
Karen Cortina	OEB/Hopi Hoekstra	Investigating the role of the motor cortex on the dexterity of deer mice	$4,000
Zoe Ann Flores	OEB/Naomi Pierce	The impact of anthropogenic change on the diversity of Massachusetts moths	$4,500
Graham Friedman	OEB/Gonzalo Giribet	Continuation of a phylogenetic investigation of the diverse millipede order, Polydesmida (Leach, 1815)	$4,500
Marissa Lynn Garcia	OEB/Gonzalo Giribet	Density estimation of North Atlantic Right Whales (*Eubalaena glacialis*) in Cape Cod Bay: Investigating aerial and acoustic survey techniques	$1,000
Gunnar Anthony Johnson	OEB/Naomi Pierce	Bottom-up effects of sodium and phosphorus stoichiometry on an ant–plant symbiosis	$4,000
Jackson Kehoe	OEB/Javier Ortega-Hernández	Testing the evolution of body segmentation in trilobites	$1,000
Dennyssed Nicole Mejia	OEB/Scott Edwards	Plastic ingestion in wedgetailed shearwaters: An analysis of blood chemistry, gene expression and body condition	$4,000
Magdalen Mercado	OEB/Stephanie Pierce	A quantitative analysis of forelimb morphology in extant quadrupeds and implications regarding emergence of modern postures and locomotory behaviors	$4,500
Araceli Meza Meza	HEB/Erin Hecht	Investigating domestication syndrome using neuropil fraction in the prefrontal cortex of silver foxes	$4,500
Logan Qualls	OEB/Javier Ortega-Hernández	Understanding intraspecific variation in *Isotelus gigas* and its impact on its existence	$3,000
Emory Sabatini	OEB/Hopi Hoekstra	Collection/analysis of *Peromyscus* pup vocalizations to determine genetics of vocal diversity	$1,000
Emory Sabatini	OEB/Hopi Hoekstra	Continued analysis of *Peromyscus* pup vocalizations with focus on cross-fostered litters	$1,000
Maddi Waskom	OEB/Javier Ortega-Hernández	Walcott-Rust trilobite imaging for Ortega-Hernández Lab	$3,500
Olivia Yoo	OEB/Hopi Hoekstra	Image analysis pipeline development to identify brain regions associated with skilled motor behavior	$4,500
		Total Awards	**$47,500**

Ernst Mayr Travel Grants in Animal Systematics

Ernst Mayr Grants support travel for research in animal systematics and are open to the scientific community worldwide. The principal objective of these grants is to stimulate taxonomic work on neglected taxa and/or poorly described species. Ernst Mayr Grants typically facilitate visits to institutional collections, with preference given to research that uses MCZ's collections. These grants are made possible by a gift from professor and former MCZ Director Ernst Mayr.

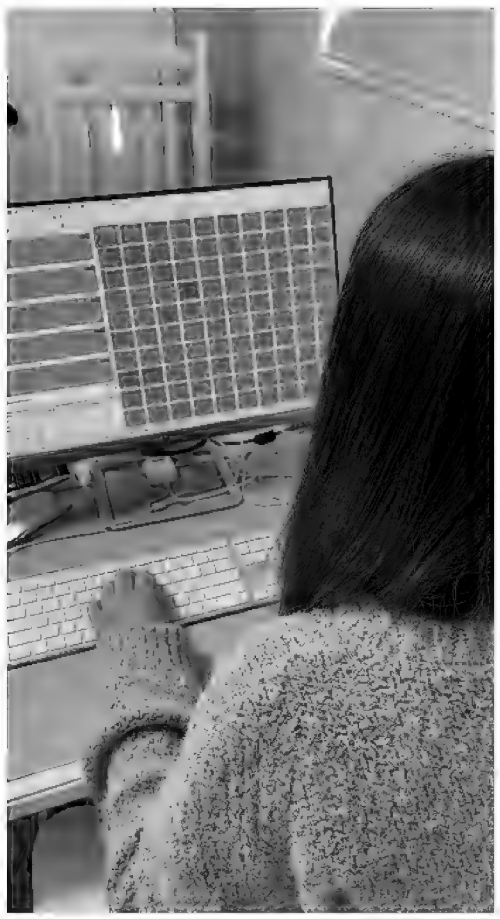
Recipient	Institutional Affiliation	Project Title	Amount
David Blackburn	University of Florida	Revision of the *Arthroleptis variabilis* species group (Anura: Arthroleptidae)	$2,000
Zachary Brown	Mississippi State University	A taxonomic revision of the genus *Stenamma* (Hymenoptera: Formicidae) with a southeastern treatment	$1,900
Vinícius Costa-Silva	University of Campinas, Brazil	A taxonomic review of genus *Polynoncus* Burmeister, 1876 (Coleoptera: Scarabaeoidea: Trogidae)	$1,200
Mario J. Cupello	Federal University of Paraná, Brazil	Unravelling the megadiversity of an adaptive radiation: Systematics of the New World dung beetle genus *Ateuchus* Weber, 1801 (Coleoptera: Scarabaeidae: Scarabaeinae)	$900
Gaurab Nandi Das	Zoological Survey of India	The complexity of Himalayan Polyommatini (Lepidoptera: Lycaenidae: Polyommatinae) taxonomy and identification, with special reference to the *Polyommatus* genus group	$2,000
Ralph Wills Flowers	Florida A&M University	Édouard Lefèvre types of Neotropical Eumolpinae (Chrysomelidae)	$1,500
Valia Herrera Alva	National University of San Marcos, Peru	Delimitation of *Pristimantis rhabdolaemus* using integrative taxonomy	$1,140
Alix Matthews	Arkansas State University	Discovering biodiversity and improving taxonomy of poorly studied symbiotic feather mites	$1,705
Williams Paredes-Munguia	Pontifical Catholic University of Rio Grande do Sul, Brazil	Phylogenetic revision of Lycosinae (Lycosidae, Araneae) genus groups	$1,500
Thiago Tadeu Silva Polizei	São Paulo State University, Brazil	Review of *Hexacylloepus* Hinton, 1940 (Insecta: Coleoptera: Elmidae)	$1,400
Carlos Alfredo Taboada Verona	University of Sucre, Colombia	Taxonomic revision of the genus *Ectenessa* Bates, 1885 (Coleoptera: Cerambycidae: Ectenessini)	$1,466
Alexandra Tokareva	Museum and Institute of Zoology, Poland	Reconstruction of the first genus-level phylogeny of Paederinae rove beetles along with several taxonomical clarifications	$1,500
		Total Awards	**$18,211**

Gaurab Nandi Das

Jenni Learned

Dennyssed Nicole Mejia

Mario J. Cupello



Marissa Lynn Garcia

Sorcha Ashe

Mario J. Cupello

Putnam Expedition Grants

Putnam Expedition Grants are intended to support MCZ faculty-curators, postdoctoral fellows and graduate students in collecting specimens and data relating to the study of comparative zoology. Priority is given to projects that collect living specimens in regions where habitats are threatened or fossil specimens in regions most likely to hold important clues for unraveling evolutionary strategies. These grants are made possible by a gift from Mr. George Putnam Jr., AB 1949 and MBA 1951, and Mrs. Nancy Putnam.

Recipient	MCZ Department/ Faculty Sponsor	Project Title	Amount
James Hanken	Herpetology	Cryptic diversity of miniaturized vertebrates: Discovering new species of Mexican salamanders, genus *Thorius*	$8,475
David Matthews	Ichthyology/George Lauder	Collecting Trinidadian guppy fish to study environmental plasticity in craniofacial adaptation	$5,304
		Total Awards	**$13,779**

Carlos Alfredo Taboada Verona

Sorcha Ashe (left) and Wendy Valencia Montoya

Ralph Wills Flowers

Publications in 2020

• **Baker CM**, Boyer SL, **Giribet G** (2020) A well-resolved transcriptomic phylogeny of the mite harvestman family Pettalidae (Arachnida, Opiliones, Cyphophthalmi) reveals signatures of Gondwanan vicariance. *J Biogeogr* 47:1345-1361 DOI: 10.1111/jbi.13828

• **Baker CM**, **Sheridan K**, **Derkarabetian S**, Pérez-González A, Vélez S, **Giribet G** (2020) Molecular phylogeny and biogeography of the temperate Gondwanan family Triaenonychidae (Opiliones : Laniatores) reveals pre-Gondwanan regionalisation, common vicariance, and rare dispersal. *Invertebr Syst* 34:637-660 DOI: 10.1071/IS19069

• Bakker FT, Antonelli A, Clarke JA, Cook JA, **Edwards SV**, et al (2020) The Global Museum: Natural history collections and the future of evolutionary science and public education. *PeerJ* 8:e8225 DOI: 10.7717/peerj.8225

• **Bishop PJ**, Bates KT, Allen VR, Henderson DM, Randau M, Hutchinson JR (2020) Relationships of mass properties and body proportions to locomotor habit in terrestrial Archosauria. *Paleobiology* 46:550-568 DOI: 10.1017/pab.2020.47

• Bittencourt JS, **Simões TR**, Caldwell MW, Langer MC (2020) Discovery of the oldest South American fossil lizard illustrates the cosmopolitanism of early South American squamates. *Commun Biol* 3:201 DOI: 10.1038/s42003-020-0926-0

• Bolívar-Leguizamón SD, Silveira LF, Derryberry EP, Brumfield RT, **Bravo GA** (2020) Phylogeography of the Variable Anthsrike (*Thamnophilus caerulescens*), a South American passerine distributed along multiple environmental gradients. *Mol Phylogenet Evol* 148:106810 DOI: 10.1016/j.ympev.2020.106810

• Braby MF, Espeland M, Müller CJ, **Eastwood R**, Lohman DJ, Kawahara AY, **Maunsell SC**, **Pierce NE** (2020) Molecular phylogeny of the tribe Candalidini (Lepidoptera: Lycaenidae): Systematics, diversification and evolutionary history. *Syst Entomol* 45:703-722 DOI: 10.1111/syen.12432

• Cadena CD, Cuervo AM, Céspedes LN, **Bravo GA**, Krabbe N, Schulenberg TS, Derryberry GE, Silveira LF, Derryberry EP, Brumfield RT, Fjeldså J (2020) Systematics, biogeography and diversification of *Scytalopus* tapaculos (Rhinocryptidae), an enigmatic radiation of Neotropical montane birds. *Auk* 137:1-30 DOI: 10.1093/auk/ukz077

• Chesser RT, Isler ML, Cuervo AM, Cadena CD, Galen SC, Bergner LM, Fleischer RC, **Bravo GA**, Lane DF, Hosner PA (2020) Conservative plumage masks extraordinary phylogenetic diversity in the *Grallaria rufula* (Rufous Antpitta) complex of the humid Andes. *Auk* 137:1-25 DOI: 10.1093/auk/ukaa009

• Clark EG, Hutchinson JR, **Bishop PJ**, Briggs DEG (2020) Arm waving in stylophoran echinoderms: Three-dimensional mobility analysis illuminates cornute locomotion. *R Soc Open Sci* 7:200191 DOI: 10.1098/rsos.200191

• **Corbett EC**, **Bravo GA**, Schunck F, **Naka LN**, Silveira LF, **Edwards SV** (2020) Evidence for the Pleistocene Arc Hypothesis from genome-wide SNPs in a Neotropical dry forest specialist, the Rufous-fronted Thornbird (Furnariidae: *Phacellodomus rufifrons*). *Mol Ecol* 29:4457-4472 DOI: 10.1111/mec.15640

• **Crall JD**, Brokaw J, Gagliardi SF, Mendenhall CD, **Pierce NE**, Combes SA (2020) Wind drives temporal variation in pollinator visitation in a fragmented tropical forest. *Biol Lett* 16:20200103 DOI: 10.1098/rsbl.2020.0103

• Dierickx EG, **Sin SYW**, van Veelen PHJ, de Brooke ML, Liu Y, **Edwards SV**, Martin SH (2020) Genetic diversity, demographic history and neo-sex chromosomes in the Critically Endangered Raso lark. *Proc R Soc B* 287:20192613 DOI: 10.1098/rspb.2019.2613

• **Dial TR**, **Lauder GV** (2020) Longer development provides first-feeding fish time to escape hydrodynamic constraints. *J Morphol* 281:956-969 DOI: 10.1002/jmor.21224

• Du KS, **Ortega-Hernández J**, Yang J, Guo QH, Li W, He JF, Li KR, Du JL, Hou JB, Zhang XG (2020) A new early Cambrian Konservat-Lagerstätte expands the occurrence of Burgess Shale-type deposits on the Yangtze Platform. *Earth-Sci Rev* 211:103409 DOI: 10.1016/j.earscirev.2020.103409

• **Edwards SV** (2020) Bicycling, birding and #BLM across America in a summer of chaos. *Biodivers Inf Sci Stand* 4:e59303 DOI: 10.3897/biss.4.59303

• **Edwards SV**, Hopkins R, **Mallet J** (2020) Speciation. In *The theory of evolution: Principles, concepts, and assumptions*. University of Chicago Press: Chicago

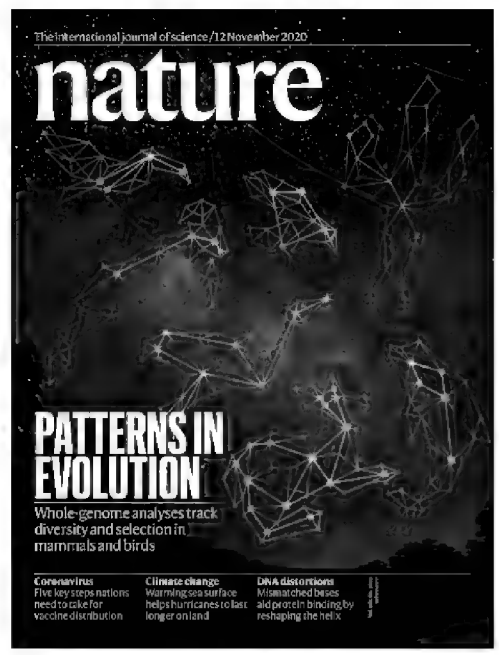
• **Edwards SV** (2020) Genomics of adaptation and acclimation: From field to lab and back. *Natl Sci Rev* 7:128-128 DOI: 10.1093/nsr/nwz173

• **Fahn-Lai P**, **Biewener AA**, **Pierce SE** (2020) Broad similarities in shoulder muscle architecture and organization across two amniotes: Implications for reconstructing non-mammalian synapsids. *PeerJ* 8:e8556 DOI: 10.7717/peerj.8556

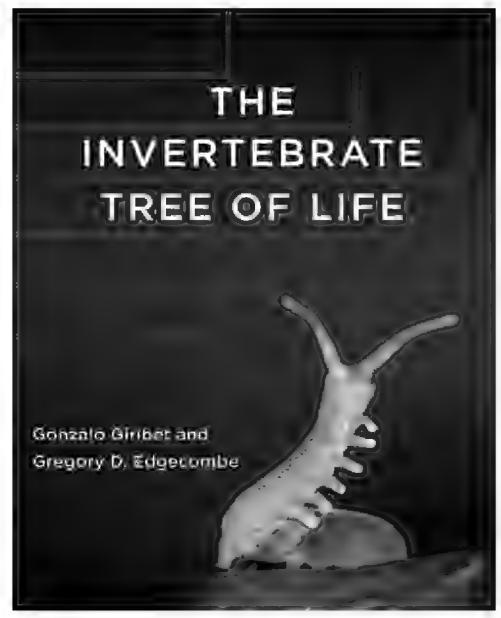
• Feng S, Stiller J, Deng Y, Armstrong J and 147 others including **Cloutier A**, **Edwards SV** (2020) Dense sampling of bird diversity increases power of comparative genomics. *Nature* 587:252-257 DOI: 10.1038/s41586-020-2873-9

• **Ferrão M**, Lima AP, Ron S, Paloma dos Santos S, **Hanken J** (2020) New species of leaf-litter toad of the *Rhinella margaritifera* species group (Anura: Bufonidae) from Amazonia. *Copeia* 108:967-986 DOI: 10.1643/CH2020043

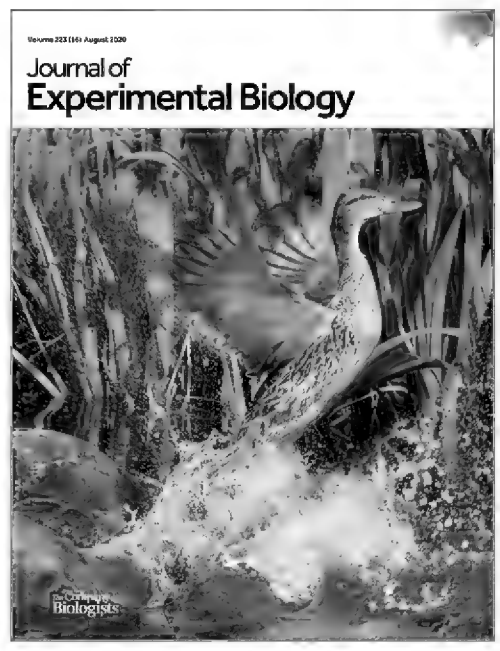
• **Ferrão M**, Moravec J, **Hanken J**, Lima AP (2020) A new species of *Dendropsophus* (Anura, Hylidae) from southwestern Amazonia with a green bilobate vocal sac. *ZooKeys* 942:77 DOI: 10.3897/zookeys.942.51864



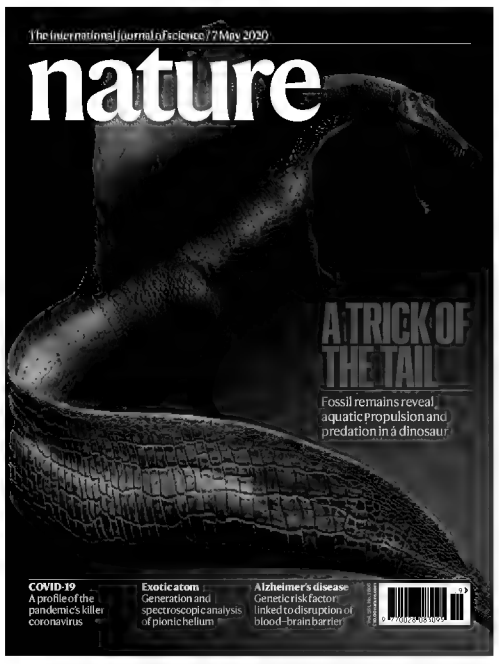
Research by **Alison Cloutier**, **Scott V. Edwards** and colleagues was featured on the cover of *Nature*.



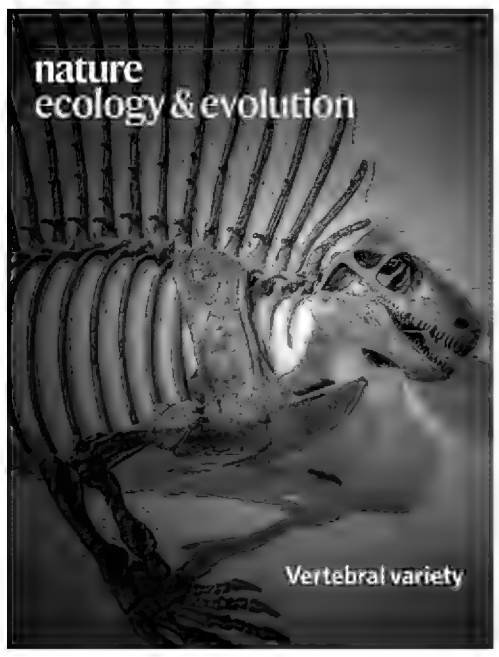
Gonzalo Giribet and **Gregory Edgecombe** are the authors of a new invertebrate zoology textbook, *The Invertebrate Tree of Life*.



The research of **Kari Taylor-Burt** and **Andrew A. Biewener** appeared on the cover of the *Journal of Experimental Biology*.



George Lauder, **Stephanie E. Pierce** and colleagues published their research in *Nature*.



The research of **Katrina Jones**, **Sarah Gonzales**, **Stephanie E. Pierce** and colleague appeared as the cover story in *Nature Ecology & Evolution*.

George V. Lauder, **Dylan Wainwright** and colleagues published their research in *Journal of the Royal Society Interface*.

• Frechette DM, **Goerig E**, Bergeron NE (2020) Factors influencing fallback by adult Atlantic salmon following transport into a novel river reach. *Fish Manag Ecol* 27:20-31 DOI: 10.1111/fme.12378

• Fried P, **Woodward J**, Brown D, Harvell D, **Hanken J** (2020) 3D scanning of antique glass by combining photography and X-ray computed tomography. *Digit Appl Archaeol Cult Heritage* 18:e00147 DOI: 10.1016/j.daach.2020.e00147

• Gainett G, Willemart RH, **Giribet G**, Sharma PP (2020) Convergent evolution of sexually dimorphic glands in an amphi-Pacific harvestman family. *Invertebr Syst* 34:871-892 DOI: 10.1071/IS20010

• Gemmell NJ and 62 others including **Edwards SV** (2020) The tuatara genome reveals ancient features of amniote evolution. *Nature* 584:403-409 DOI: 10.1038/s41586-020-2561-9

• **Gilbert KJ**, **Bittleston LS**, Naive MAK, Kiszewski AE, Buenavente PAC, Lohman DJ, **Pierce NE** (2020) Investigation of an elevational gradient reveals strong differences between bacterial and eukaryotic communities coinhabiting *Nepenthes* phytotelmata. *Microb Ecol* 80:334-349 DOI: 10.1007/s00248-020-01503-y

• **Gilbert KJ**, **Bittleston LS**, Tong W, **Pierce NE** (2020) Tropical pitcher plants (*Nepenthes*) act as ecological filters by altering properties of their fluid microenvironments. *Sci Rep* 10:4431 DOI: 10.1038/s41598-020-61193-x

• **Giribet G** (2020) An updated catalogue of the Opiliones suborder Cyphophthalmi (Arthropoda, Arachnida). *Rev Iber Aracnol* 37:61-100

• **Giribet G** (2020) Genomes: Miniaturization taken to extremes. *Curr Biol* 30:R314-R316 DOI: 10.1016/j.cub.2020.02.044

• **Giribet G, Edgecombe GD** (2020) *The Invertebrate Tree of Life*. Princeton University Press: Princeton and Oxford

• **Goerig E**, Wasserman BA, Castro-Santos T, Palkovacs EP (2020) Body shape is related to the attempt rate and passage success of brook trout at in-stream barriers. *J Appl Ecol* 57:91-100 DOI: 10.1111/1365-2664.13497

• Gordon JC, Holt NC, **Biewener AA**, Daley MA (2020) Tuning of feedforward control enables stable muscle force-length dynamics after loss of autogenic proprioceptive feedback. *eLife* 9:e53908 DOI: 10.7554/eLife.53908

• Greenwood L, Loader SP, Lawson L, Greenbaum E, **Zimkus BM** (2020) A new species of *Phrynobatrachus* (Amphibia: Anura: Phrynobatrachidae) from the Northern Mountains of Tanzania. *J Nat Hist* 54:63-85 DOI: 10.1080/00222933.2020.1757171

• Gvoždík V, Nečas T, Dolinay M, **Zimkus BM**, Schmitz A, Fokam EB (2020) Evolutionary history of the Cameroon radiation of puddle frogs (Phrynobatrachidae: *Phrynobatrachus*), with descriptions of two critically endangered new species from the northern Cameroon Volcanic Line. *PeerJ* 8:e8393 DOI: 10.7717/peerj.8393

• Han P, **Lauder GV**, Dong H (2020) Hydrodynamics of median-fin interactions in fish-like locomotion: Effects of fin shape and movement. *Phys Fluids* 32:011902 DOI: 10.1063/1.5129274

• Harvey MG, **Bravo GA**, Claramunt S, Cuervo AM, Derryberry GE, Battilana J, Seeholzer GF, McKay JS, O'Meara BC, Faircloth BC, **Edwards SV**, et al (2020) The evolution of a tropical biodiversity hotspot. *Science* 370:1343-1348 DOI: 10.1126/science.aaz6970

• **Hedrick BP**, **Dickson BV**, Dumont ER, **Pierce SE** (2020) The evolutionary diversity of locomotor innovation in rodents is not linked to proximal limb morphology. *Sci Rep* 10:1-11 DOI: 10.1038/s41598-019-57144-w

• **Hedrick BP**, Heberling MJ, Meineke EK, Turner KG, Grassa CJ, Park DS, Kennedy J, Clarke JA, Cook JA, Blackburn DC, **Edwards SV**, Davis CC (2020) Digitization and the future of natural history collections. *BioScience* 70:243-251 DOI: 10.1093/biosci/biz163

• **Hulett RE**, Potter D, **Srivastava M** (2020) Neural architecture and regeneration in the acoel *Hofstenia miamia*. *Proc R Soc B* 287:20201198 DOI: 10.1098/rspb.2020.1198

• Ibrahim N, Maganuco S, Dal Sasso C, Fabbri M, Auditore M, Bindellini G, Martill DM, Zouhri S, Mattarelli DA, Unwin DM, Wiemann J, Bonadonna D, Amane A, Jakubczak J, Joger U, **Lauder GV**, **Pierce SE** (2020) Tail-propelled aquatic locomotion in a theropod dinosaur. *Nature* 581:67-70 DOI: 10.1038/s41586-020-2190-3

• Jiang X, **Edwards SV**, Liu L (2020) The multispecies coalescent model outperforms concatenation across diverse phylogenomic data sets. *Syst Biol* 69:795-812 DOI: 10.1093/sysbio/syaa008

• Johanson Z, Jeffery J, Challands T, **Pierce SE**, Clack JA (2020) A new look at Carboniferous Rhizodontid humeri (Sarcopterygii; Tetrapodomorpha). *J Vertebr Paleontol* 40:e1813150 DOI: 10.1080/02724634.2020.1813150

• **Jones KE**, **Gonzalez S**, Angielczyk KD, **Pierce SE** (2020) Regionalization of the axial skeleton predates functional adaptation in the forerunners of mammals. *Nat Ecol Evol* 4:470-478 DOI: 10.1038/s41559-020-1094-9

• Kallal RJ, Dimitrov D, **Arnedo MA**, **Giribet G**, Hormiga G (2020) Monophyly, taxon sampling and the nature of ranks in the classification of orb-weaving spiders (Araneae: Araneoidea). *Syst Biol* 69:401-411 DOI: 10.1093/sysbio/syz043

• **Knutson VL**, Brenzinger B, Schrödl M, Wilson NG, **Giribet G** (2020) Most Cephalaspidea have a shell, but transcriptomes can provide them with a backbone (Gastropoda: Heterobranchia). *Mol Phylogenet Evol* 153:106943 DOI: 10.1016/j.ympev.2020.106943

• **Konow N**, Collias A, **Biewener AA** (2020) Skeletal muscle shape change in relation to varying force requirements across locomotor conditions. *Front Physiol* 11:143 DOI: 10.3389/fphys.2020.00143

• **Lerosey-Aubril R**, Kimmig J, **Pates S**, Skabelund J, Weug A, **Ortega-Hernández J** (2020) New exceptionally preserved panarthropods from the Drumian Wheeler Konservat-Lagerstätte of the House Range of Utah. *Pap Palaeontol* 6:501-531 DOI: 10.1002/spp2.1307

• **Lerosey-Aubril R**, Skabelund J, **Ortega-Hernández J** (2020) Revision of the mollisoniid chelicerate(?) *Thelxiope*, with a new species from the middle Cambrian Wheeler Formation of Utah. *PeerJ* 8:e8879 DOI: 10.7717/peerj.8879

• Lewandowski JP, Dumbović G, Watson AR, Hwang T, **Jacobs-Palmer E**, Chang N, Much C, Turner K, Kirby C, Schulz JF, Muller C-L, Rubenstein ND, Groff AF, Liapis SC, Gerhardinger C, Hubner N, van Heesch S, **Hoekstra HE**, Sauvageau M, Rinn JL (2020) The Tug1 lncRNA locus is essential for male fertility. *Genome Biol* 21:237 DOI: 10.1186/s13059-020-02081-5

• Li J, **Lemer S**, Kirkendale L, Bieler R, Cavanaugh CM, **Giribet G** (2020) Shedding light: A phylotranscriptomic perspective illuminates the origin of photosymbiosis in marine bivalves. *BMC Evol Biol* 20:50 DOI: 10.1186/s12862-020-01614-7

• **Liu C**, Fischer G, Garcia FH, Yamane S, Liu Q, Peng YQ, Economo EP, Guénard B, **Pierce NE** (2020) Ants of the Hengduan Mountains: A new altitudinal survey and updated checklist for Yunnan Province highlight an understudied insect biodiversity hotspot. *ZooKeys* 978:1-171 DOI: 10.3897/zookeys.978.55767

• Liu Y, **Lerosey-Aubril R**, Audo D, Zhai D, Huijuan M, **Ortega-Hernández J** (2020) Occurrence of the eudemersal radiodont *Cambroraster* in the early Cambrian Chengjiang Lagerstätte and the diversity of hurdiid ecomorphotypes. *Geol Mag* 157:1200-1206 DOI: 10.1017/S0016756820000187

• Liu Y, **Ortega-Hernández J**, Chen H, Mai H, Zhai D, Hou XG (2020) Computer tomography sheds new light on the affinities of the enigmatic euarthropod *Jianshania furcatus* from the early Cambrian Chengjiang biota. *BMC Evol Biol* 20:62 DOI: 10.1186/s12862-020-01625-4

• Liu Y, **Ortega-Hernández J**, Zhai D, Hou XG (2020) A reduced labrum in a Cambrian great-appendage euarthropod. *Curr Biol* 30:3057-3061 DOI: 10.1016/j.cub.2020.05.085

• Lopes Ferreira R, **Giribet G**, Du Preez G, Ventouras O, Janion C, Souza Silva M (2020) The Wynberg Cave System, the most important site for cave fauna in South Africa at risk. *Subterr Biol* 36:73-81 DOI: 10.3897/subtbiol.36.60162

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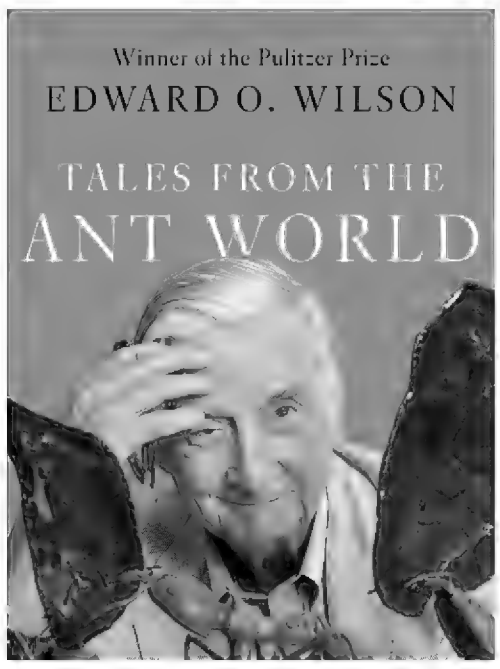
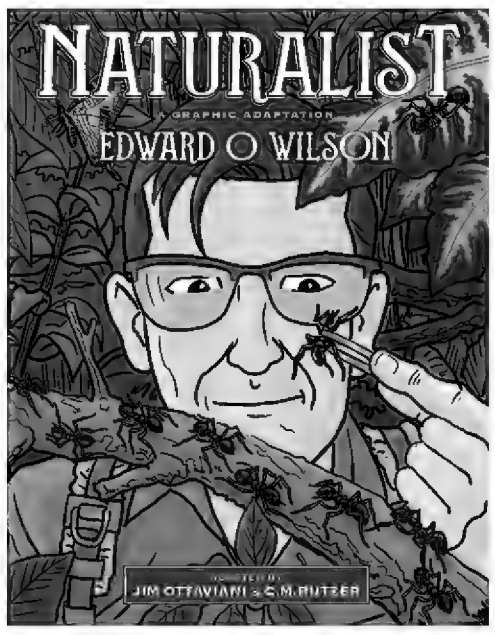


Edward O. Wilson published *Tales from the Ant World.*



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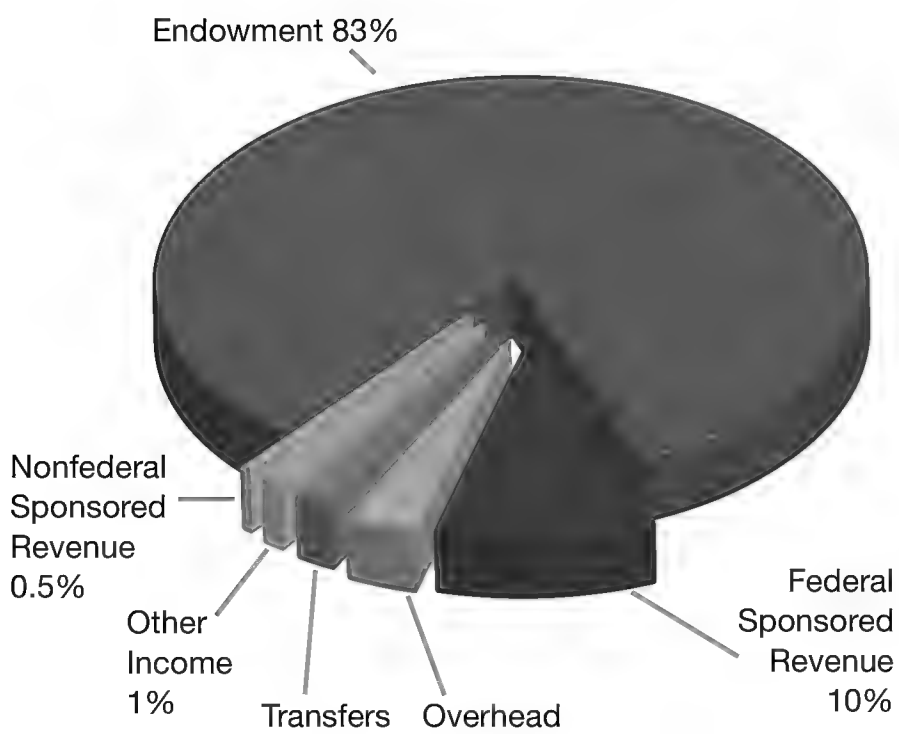
Financial Data

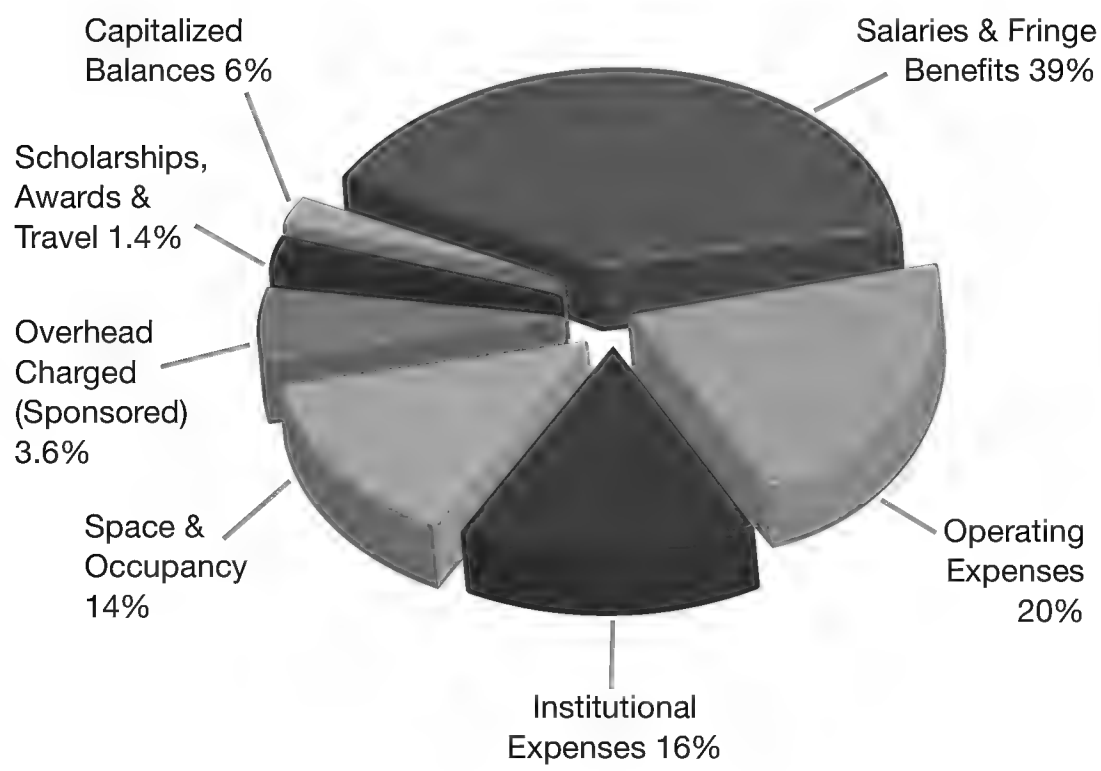
These charts describe the income and expenses of the Museum of Comparative Zoology in fiscal year 2020.

Endowment income funds much of the Museum's activities, such as acquisition and maintenance of collections, faculty and staff salaries, capital projects, and facilities renovation and maintenance. It includes the annual distribution (payout) and endowed funds decapitalized per donor request. **Gifts** are donations received in support of Museum activities that are available for current use; it does not include donations for endowed funds. **Transfers** include financial support for the Ernst Mayr Library and other Harvard-funded activities. **Other Income** comprises miscellaneous income from publication subscriptions, royalties, sales and fees, and cost recovery from other MCZ-sponsored activities. **Overhead** is funds paid from sponsored projects to cover associated facilities and administrative costs. It is shown as both income (**Overhead Earned**) and expenses (**Overhead Charged**). Accumulation of **Unrestricted Reserves** indicates net growth of balances in unrestricted gifts and endowments from, for example, interest payments and unspent portions of the current year's endowment payouts. **Draw on Restricted Reserves** indicates restricted fund balances utilized to fund operations. Building expenses such as maintenance, facility improvements and utilities are captured in the **Space & Occupancy** category. **Operating Expenses** consist of equipment purchases, supplies, and consultant and conference fees, as well as annual subventions for administrative services and MCZ support for faculty-curator research. Support for MCZ-affiliated graduate students in OEB is included in **Scholarships, Awards & Travel. Institutional Expenses** are support for other University activities outside the MCZ, including FAS and University initiatives and general operating support to the Harvard Museums of Science and Culture.

INCOME



EXPENSES & NON-OPERATING FUNDS



Income

Endowment	$16,451,393
Federal Sponsored Revenue	$1,888,291
Overhead Earned	$703,953
Transfers	$396,792
Other Income	$161,357
Nonfederal Sponsored Revenue	$100,867
Drawdown of Restricted Reserves	$24,074
Gifts	$3,050
Accumulation of Unrestricted Reserves	($139,424)
Total	**$19,590,353**

Expenses

Salaries & Fringe Benefits	$7,669,933
Operating Expenses	$3,972,463
Institutional Expenses	$3,043,809
Space & Occupancy	$2,684,981
Capitalized Balances	$1,240,600
Overhead Charged (Sponsored)	$703,953
Scholarships, Awards & Travel	$274,615
Total	**$19,590,353**

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The MCZ deeply appreciates the additional support and contributions of numerous interns and undergraduate students during the 2020–2021 academic year.

MCZ Faculty

The MCZ's charter, signed in 1859, mandates that the Museum's activities will be overseen by a governing board, the Faculty of the Museum of Comparative Zoology.

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Mr. Jeff Tarr

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Mr. Paul J. Zofnass

President Lawrence S. Bacow

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